CASTOR BEAN, *Ricinus communis* L., AS A HOST OF *Liriomyza* LEAFMINERS (Diptera:Agromyzidae) IN THE EVERGLADES AGRICULTURAL AREA OF SOUTH FLORIDA

By

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Abstract of Dissertation Presented to the Graduate School of the University of Florida in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy

CASTOR BEAN, Ricinus communis L., AS A HOST OF Liriomyza LEAFMINERS (Diptera:Agromyzidae) IN THE EVERGLADES AGRICULTURAL AREA OF SOUTH FLORIDA

By

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A field study determined castor bean, Ricinus communis L., the most prominent host of leafminers and leafminer parasitoids of three weeds tested. Active mine populations peaked at 22 per 5000 sq. cm of castor bean foliage during the first sampling period (May 24, 1984). Liriomyza sativae Blanchard and L. trifolii (Burgess) accounted for all leafminer adults reared from foliage with the former comprising 63.3% of specimens collected.

Eleven species of parasitoids were reared from Liriomyza. Opius spp. and Halticoptera circulus (Walker) were the most abundant. More than 9.6 adult parasitoids per 5000 sq. cm of foliage were reared May 24 and parasitism rates as high as 100% occurred during three other sampling

periods. Abundance and performance of parasitoids varied with castor bean canopy layer.

Leafminer abundance on castor bean peaked again in March and April 1985 with 37 active mines per 9 m^2 plot occurring on April 22. Liriomyza sativae comprised 74.5% of Liriomyza collected from August 1984 to July 1985. Opius spp. accounted for >85% of parasitoids reared and percent parasitism peaked during the weeks of April 8 and July 16 at 94.8 and 100%, respectively.

Celery trifoliate collections suggested castor bean perhaps influenced leafminer parasitism in celery rows nearest the weed. Liriomyza trifolii was the only leafminer reared from celery and Diglyphus intermedius (Girault) was the most abundant parasitoid reared from celery and collected on sticky traps.

Liriomyza trifolii females exhibited a significant preference for celery as an oviposition substrate over castorbean. Castor bean was preferred by L. sativae females for oviposition as they virtually rejected celery as a host.

Development times for combined egg and larval stages were 13.22, 8.75, 6.31 and 6.17 d at 20, 25, 30 and 35° C for L. sativae on castor bean. Pupal development times were 15.33, 9.61 and 6.81 d at 20, 25 and 30° C. No pupae survived at 35° C. Females produced a mean of 164.49 larvae at 25° C on castor bean over an average lifespan of 13.36 d. Fecundity peaked at five days of age.

CHAPTER I
INTRODUCTION

Celery, Apium graveoluns L. var. dulce, is one of the major vegetable crops grown in Florida with 9300 acres planted in 1984-85, 7295 of those in the Everglades Agricultural Area around Belle Glade (Anon. 1986). A record total monetary value of $64,546,000 was recorded in 1983-84 (Anon. 1986) when the net return for growers in the Everglades region averaged $657.31 per acre (Taylor and Locascio 1985). A considerable amount of money ($680 per acre in 1983-84), however, is spent attempting to control pestiferous insect, weed and fungus species (Taylor and Locascio 1985) which would otherwise devastate the crop.

The leafmining fly Liriomyza trifolii (Burgess) is considered the most important insect pest of celery in the Belle Glade area (Guzman et al. 1973). Approximately half of insecticide costs for celery can be appropriated for control of L. trifolii with as many as three treatments applied per week (M.D. Pemick, personal communication, 1987). Adult females damage leaves by ovipositing and creating feeding punctures. Larvae mine the leaves reducing photosynthetically active tissue, providing entry points for pathogens and causing cosmetic damage (Musgrave et al. 1978). The tremendous reproductive potential of L.

trifolii, ca. three times that of other economically important Liriomyza spp. (Parrella and Keil 1984), enables the pest to reach exceedingly high densities in relatively short periods of time.

Although L. trifolii is currently the dominant, if not only, leafminer species attacking celery in Florida, earlier reports implicated a very similar species, L. sativae Blanchard, as the major pest. A shift in dominance from the latter to the former species may have occurred as a result of L. trifolii's greater tolerance to insecticides (Parrella and Keil 1984). However, a shift in dominance may never have occurred. Rather, L. trifolii may have been misidentified as L. sativae and/or its synonyms in these early studies as the two are sympatric, highly polyphagous (sharing many of the same host plants) and very similar morphologically (Spencer and Steqmaier 1973, Stegmaier 1981). The doubts surrounding this possible misidentification have impeded interpretation of results of earlier studies and hampered their utilization in recent control efforts.

The aforementioned tolerance to insecticides is probably the major cause for L. trifolii's prominence among celery pests. The widespread, sometimes nonjudicious use of a variety of compounds on celery and other vegetables (Leibee 1981) coupled with the species' large reproductive potential have inevitably allowed for the evolution and continuation of insecticide resistance. Also, considerable

mortality potentially inflicted by the large parasitoid complex attacking L. trifolii has been negated in most cases by the detrimental effects of insecticides upon the parasitoids, further aggravating the problem (Poe et al. 1978, Waddill 1981).

The failure of various chemical insecticides to provide adequate and economically sound leafminer control plus increasing concern of the effects of such compounds within the environment have prompted research of control tactics and insecticides emphasizing the conservation and utilization of parasitoids (Genung et al. 1978, Schuster and Price 1985, Trumble and Toscano 1983, Trumble 1985). The contribution host plants other than the crop may make towards parasitoid incidence has also been reported. Schuster et al. (1982) found high rates of Liriomyza parasitism occurring on weeds near tomato fields on Florida's gulf coast while Genung and Janes (1975) and Genung et al. (1978) working near Belle Glade noted higher rates of leafminer parasitism in celery nearest field borders adjacent to weeds. Genung (1981) stated certain weeds which harbor natural enemies of Liriomyza may even be considered beneficial when occurring near celery fields.

Despite this knowledge, no studies have been undertaken to examine this component of the celery agroecosystem in south Florida. Certain weed species in this region are reported to serve as hosts of L. sativae but not L. trifolii (Stegmaier 1981). Also, the two leafminer

species are attacked by many of the same parasitoids (Chandler 1982, Stegmaier 1981). Considering these reports plus the fact that L. sativae in Florida presumably no longer attacks celery, the potential exists for the manipulation of a weed host of L. sativae in hopes of increasing parasitism of L. trifolii within celery.

The objectives of the following studies were to investigate this comparatively unknown area of leafminer biological control by first determining leafminer and leafminer parasitoid incidence and abundance on weeds reported as hosts of Liriomyza species in south Florida; to determine the effect of castor bean, Ricinus communis L., on Liriomyza and parasitoid occurrence within adjacent celery plots; and to determine the preference for celery and castor bean by L. trifolii and sativae as well as the biology of the latter on castor bean.

CHAPTER II
LITERATURE REVIEW

Systematics of Liriomyza trifolii (Burgess) and L. sativae Blanchard

There are over 300 species of Liriomyza worldwide, 78 within the United States, and many are polyphagous (Spencer 1981b). The taxonomic history of the genus is marked by confusion and misidentifications and only recently has the systematics of this group been relatively clarified (Spencer 1973, Spencer and Stegmaier 1973, Spencer 1981a). Indicative of this confusion are the taxonomic histories of L. trifolii and L. sativae.

Burgess in 1880 first described L. trifolii as Oscinis trifolii collected on white clover in the District of Columbia. O. trifolii and O. brassicae Riley were synonymized with Agromyza diminuta Walker by Coquillet (1898) and Malloch (1913) synonymized O. trifolii and C. brassicae with A. pusilla Meigen. Melander (1913) synonymized A. diminuta Walker with A. scutellata Fallen and used the name Liriomyza without placing A. scutellata in it. A. pusilla was reported to occur on 24 different host species by Webster and Parks (1913) although Spencer (1981b) later reported they were working with L. trifolii, L. sativae, L. huidobrensis (Blanchard) and other species.

In 1925 de Meijere placed O. trifolii in the genus Liriomyza and noted the synonymy of A. trifolii (Burgess) Coquillet 1898 and A. trifolii Kaltenbach 1874 (Zoebisch 1984), now considered a homonymy of A. nana (Meigen) 1830 (Spencer 1981b). Zoebisch (1984) stated this homonymy violates article 35 of the International Commission on Zoological Nomenclature (Schenk and McMasters 1936), thus, L. trifolii should be renamed. L. allivora (Frick 1955) and L. archiboldi (Frost 1962) have recently been synonymized with L. trifolii by Spencer (1981a).

L. sativae, occurring on alfalfa in Argentina, was first described by Blanchard in 1938 (Spencer 1981a). In 1952 Frick described three species from Hawaii, L. pullata, canomarginis, and minuseta, all synonymized with L. sativae by Spencer (1973). Spencer also synonymized L. munda reared from tomatoes in California by Frick (1957) with L. sativae (Spencer 1973). L. guytona Freeman (1958) collected in Alabama was synonymized with L. munda by Steyskal (1964) and later with L. sativae by Spencer (1973). In 1973 Steyskal synonymized L. propepusilla Frost with L. munda. L. propepusilla had originally been described as A. subpusilla by Frost in 1943 but was renamed by him in 1954.

Frick (1957) applied the name A. pictella, originally described by Thomson in 1869 (Spencer 1981b), to specimens he reared from 16 different hosts. Spencer (1981b) notes he was dealing with at least six different species , one being a color variant of L. sativae. The name pictella, however,

became widely used and Oatman and Michelbacher (1958) and Oatman (1959a,1959b) published studies on the biology, ecology, and host range of L. pictella, the "melon leafminer." Crossbreeding studies utilizing L. pictella and L. sativae (as L. munda), the "tomato leafminer," were also conducted (Catman 1961). Spencer (1981b) believes the "melon leafminer" and L. munda of these experiments to possibly represent different host strains differentiating on tomato and melon. No specimens were preserved, disallowing later determinations of the species. Jensen and Koehler (1970) reported on the seasonal and distributional abundance of two species on alfalfa, L. sativae (as L. munda) and L. trifoliearum, which was undescribed at the time but misidentified by the authors as L. pictella (Spencer 1981b).

Spencer (1973) noted L. sativae and L. trifolii could be easily confused. They are quite similar morphologically, sympatric and they have several host plants in common (Stegmaier 1981). To add to the confusion, Poe and Montz (1981) suggested that the predominance within a host crop may shift from one species to another due to differential resistance to particular insecticides. Therefore, even recent reports and studies concerning L. sativae and L. trifolii may contain a misidentification of one species as the other.

Descriptions of L. trifolii and L. sativae

L. trifolii and sativae adults are very small flies with wing lengths of 1.25-1.90 mm and 1.25-1.70 mm, respectively (Spencer 1981a). Spencer (1965) described a neotype of L. trifolii stored in the U.S. National Museum and Spencer and Stegmaier (1973) gave a similar description:

> Orbits entirely yellow, both vertical bristles on yellow ground; all antennal segments bright yellow, third with inconspicuous pubescence; mesonotum blackish gray, distinctly mat, acrostichals in 3 or 4 rows in front, reduced to 2 rows behind, yellow patch at each hind corner adjoining scutellum, mesopleura with black patch extending along lower margin; abdomen with tergites variably yellow laterally and on hind margins; legs: coxae yellow, femora largely so but with slight, variable brownish striation; tibia and tarsi darker, brown (p. 109).

Although very similar in appearance, L. sativae adults differ morphologically from those of L. trifolii in several characteristics. The hind margin of the eye of L. sativae is entirely dark, or nearly so, extending to the base of the outer vertical bristle and frequently along the upper orbits beside the eye margin. Even more conspicuous is the mesonotum which is deep black and shining on L. sativae (Spencer 1981b). To make a definite distinction between the two species, the aedeagus must be examined. Spencer and Stegmaier (1973) and Spencer (1981a) gave illustrations of the male genitalia of the two species.

Differences in female genitalia were described by Knodel-Montz and Poe (1982) using scanning electron microscopy. The denticles of L. trifolii are angular and the egg-guide is V-shaped while the denticles and egg-guide of L. sativae are elongate and acutely angled, respectively. Zehnder et al. (1983), using scanning electron microscopy, found a dense covering of microsetae on the mesonotum of L. trifolii which gives it a mat-grey appearance. The shiny black mesonotum of L. sativae resulted from having few microsetae.

The larvae and leafmines of the two species are very similar and can not be distinguished visually although Spencer and Steqmaier (1973) noted the mines of L. trifolii are generally longer. Menken and Ulenberg (1986), however, distinguished between the larvae as well as the pupae and adults of four Liriomyza species, including trifolii and sativae, by allozyme analysis using starch gel electrophoresis. Different enzyme mobilities were also reported by Zehnder et al. (1983) for L. trifolii, sativae and brassicae. Host food and geographic site of location did not influence enzyme mobility for conspecific strains of L. trifolii and sativae.

Distributions and Host Ranges

Although distributed throughout the world, the genus Liriomyza is best represented in the neotropical region (Spencer and Stegmaier 1973, Spencer 1981a). L. trifolii has been recorded from North America, South America, the Caribbean, Africa and Europe (Eartlett and Powell 1981, d'Aguillar and Martinez 1979, deLima 1979, Fagoonee and Toory 1984, Frick 1959, Poe and Montz 1981, Spencer 1985, Spencer and Stegmaier 1973). Ontario is the northern limit of its range (Spencer and Stegmaier 1973) and it has been reported as far south as Colombia (Poe and Montz 1981).

Much of the movement of L. trifolii into areas outside of North America is believed to have occurred on infested plant parts (Poe and Montz 1981). Reports and outbreaks of L. trifolii in Kenya (deLima 1979), the Netherlands (Spencer 1981a), Great Britain (Anon. 1977) and Colombia (Price 1982) are believed to have resulted from importation of infested chrysanthemum cuttings from the U.S., particularly Florida (Price 1981, Spencer 1981a).

L. sativae is recorded from Alabama, California, Florida, Ohio, South Carolina, Tennessee and Texas, and from Mexico, Central America, South America, Cuba, Jamaica and Barbados (Musgrave et al. 1975b, Spencer 1981a). Although reported from Hawaii, Guam and Tahiti, occurrences in these areas are probably due to recent introductions (Musgrave et al. 1975b).

Both species are highly polyphagous and many hosts are attacked by both species. Patel (1986) compiled a list of hosts for L. trifolii from sources published since 1981 when Spencer's report (1981b) alleviated much of the confusion concerning identification of the species. Patel (1986) recorded 144 hosts worldwide in 32 families, the most widely attacked being Asteraceae (=Compositae) (46 spp.), Cruciferae (10 spp.), Cucurbitaceae (8 spp.), Fabaceae (=Leguminosae) (17 spp.) and Solanaceae (12 spp.).

L. sativae (as L. munda) was found on 37 host species in 10 families in Florida (Stegmaier 1966a). Musgrave et al. (1975b) reported 60 hosts of L. sativae in 14 families, with Asteraceae (=Compositae) (16 spp.), Fabaceae (=Leguminosae) (14 spp.) and Solanaceae (9 spp.) most heavily attacked. The most economically important host species reported for L. sativae occur in the families Curcubitaceae (watermelon, cucumber and squash), Fabaceae (=Leguminoseae) (alfalfa, clover, peas and lima beans), Solanaceae (tomato, eggplant and potato) and Umbelliferae (celery and carrot) (Musgrave et al. 1975b, Tryon 1979).

Life History and Biology

A Liriomyza (Liriomyza = L. trifolii and L. sativae) female lays eggs singly within the leaf mesophyll, inserting

her ovipositor through the epidermis, creating a puncture or "stipple". A female often creates stipples without depositing eggs, feeding from the exudates of ruptured cells (Trumble 1981). Oviposition stipples are smaller than feeding stipples (Zoebisch 1984). Eggs are oblong, creamy white, and 0.25 to 0.30 mm long and 0.10 to 0.20 mm wide (Patel 1986). Eggs increase in size after deposition and darken as they mature (Dimetry 1971, Patel 1986).

Upon hatching the first instar begins feeding upon the palisade parynchema cells creating a serpentine mine which widens as the larva develops. Newly emerged larvae are 0.12 mm long (Patel 1986) and mature through three instars to a length of two to three mm (Zoebisch 1984). Completing development, a third instar larva chews a semicircular hole in the epidermis, exits the leaf and drops to the ground to pupate.

Liriomyza pupates, as do all cyclorrhaphan Diptera, within the cuticle of the last larval instar, the puparia. Adults can mate within one day of emergence (Patel 1986) and females feed from stippling punctures, while males apparently do not (Zoebisch and Schuster, unpublished data). Both have been demonstrated to feed from other nutrient sources such as honeydew (Zoebisch and Schuster, unpublished data).

Developmental times for Liriomyza life stages are affected by temperature and may also vary with host plant. Egg development of L. trifolii on celery was 1.99 d at 35^{0}

C, but 9.97 d at 15° C (Leibee 1984). Charlton and Allen (1981) reported similar results for L. trifolii on pink beans (Phaseolus sp.); however, at lower temperatures (20 and 25° C) egg development took longer when chrysanthemum was the host.

Larval development of L. trifolii on pink beans ranged from 3.4 d (32.5° C) to 30.9 d (13.8° C) (Charlton and Allen 1981). Similar development times were recorded for L. trifolii on chrysanthemums (Charlton and Allen 1981) and tomato (Schuster and Patel 1985). Celery, however, apparently increases L. trifolii larval development time. Larvae feeding on celery required 3.1, 3.5, 5.3 and 13.2 d longer to develop at 30, 25, 20 and 15° C, respectively, than when utilizing pink beans as a host (Charlton and Allen 1981, Leibee 1984).

Pupal development times for L. trifolii on celery decreased from 28.2 d at 15 °C to 6.7 d at 35° C (Leibee 1984). Pupae of L. trifolii individuals reared on pink beans and chrysanthemums exhibited similar development times (Charlton and Allen 1981).

Longevity of adults is dependent on availability and quality of food source as well as temperature. Unfed adult L. trifolii survived only 3 d at 23.8° C (Charlton and Allen 1981). In the same study females and males lived 7.2 and 2.3 d, respectively, when offered blackeyed pea foliage, but 22.7 and 13.9 d, respectively, when offered the same foliage plus honey. Female L. trifolii ovipositing and feeding on

celery survived 13.0 d at 35° C and 27.7 d at 15° C with a 10% honey supplement (Leibee 1984). Parrella (1984) reported L. trifolii adults lived for 3.1 and 16.7 d at 37.8 and 15.6° C, respectively, on chrysanthemum and honey.

Fecundity is also apparently affected by temperature, nutrient availability, and in addition, age of female. L. trifolii produced an average of 177 eggs per female on blackeyed pea foliage and 439 eggs when presented foliage plus honey (Charlton and Allen 1981). L. trifolii females were most fecund at 26.7° C averaging 278.9 eggs per individual and least fecund at 37.8° C (0.9 egg per individual) on chrysanthemum on honey (Parrella 1984). On celery, females with a honey supplement produced considerably more eggs with a maximum of 405.7 per individual deposited at 30° C (Leibee 1984). Only 24.3 eggs were produced at 35° C.

Greatest egg deposition per female per day (35 to 39 eggs) occurred at 1, 2 and 4 d of age at 35, 30 and 25° C, respectively (Leibee 1984). Parrella (1984) found greatest oviposition occurred at 2, 4, 8, 10 and 16 d of age at 37.8, 32.2, 26.7, 21.1 and 15.6° C, respectively, for L. trifolii.

Extremes in temperature are known to influence mortality of L. trifolii pupae. Ninety-two percent of pupae perished at 35° C; however, only 10% died at 15° C (Leibee 1984). All pupae reared from chrysanthemum died at 37.8° C (Parrella et al. 1983b).

Results of Charlton and Allen (1981) suggest host species may affect leafminer survival. Total percent mortality for L. trifolii was 26.9, 26.8, 52.6 and 99.0 when reared on pink bean, blackeyed pea, `Show-off' chrysanthemum and `Yellow Knight' chrysanthemum, respectively.

L. trifolii apparently exhibits a diurnal pattern in its behavior. Charlton and Allen (1981) found larval emergence occurs most frequently from 0830 to 1230 and adult emergence from the soil peaks from 0930 to 1230. No adult emergence occurred before 0830 and after 1430. Most eggs are deposited from 1130 to 1530. Feeding occurred throughout the daylight hours.

Due to the emergence of L. trifolii as the dominant economic pest in the last 10 years, most recent biological studies have been concerned with this species. Earlier results from studies of L. sativae, as L. pictella (Catman and Michelbacher 1958, Catman 1959a, 1960) and as part of the serpentine leafminer complex (Cenung and Harris 1961), are questionable since it is possible L. sativae was not the only species involved.

Control of Liriomyza on Celery

Chemical Control

Leafminers were not considered pests of celery and other vegetables in Florida until the mid-1940s when the use of chlorinated hydrocarbon insecticides became widespread (Baranowski 1958, Leibee 1981). Chlordane was recommended for leafminer control on potatoes by Wolfenbarger (1947); however, it and other chlorinated hydrocarbons such as BHC and aldrin had lost their effectiveness after the first or second season of use (Wolfenbarger 1958). Since then, several insecticides reported in the past as giving satisfactory leafminer control have become ineffective. Leibee (1981) gave an account of the history of leafminer control with insecticides which is summarized below.

Toxaphene gave satisfactory control from 1947 to 1952, then decreased in effectiveness as did parathion, after 10 years of use, by the 1956-57 season. Diazinon, recommended for only two to three years, provided poor control on vegetables in south Florida by the early 1960s. Reported as giving adequate control on celery in 1962, diazinon and naled had become ineffective by 1974, as had azinphos-methyl. Dimethoate, approved for use on celery in that year, also failed to give a desired level of control. Oxamyl and permethrin, approved for celery use in 1975 and 1978, respectively, became relatively ineffective in two

years or less and methamidiphos, registered in 1977, has exhibited decreased effectiveness.

The history of leafminer control in California, another major celery-producing region, is not as involved as that of Florida. The major leafminer pest of celery there, up until ca. 1980, was L. sativae which only reached economic levels every five to 10 years and is satisfactorily controlled with insecticides (Trumble 1981). However, L. trifolii, supposedly introduced from Florida, emerged as the major pest since ca. 1980 and its history of resistance to insecticides in California is consistent with those from other states where this species is a serious problem (Parrella et al. 1981a).

Insecticide resistance due to extensive use of these compounds and the detrimental effects they have upon leafminer parasitoids have resulted in an almost complete breakdown of past Liriomyza control programs. Use of DDT for celery pests other than leafminers probably caused cross resistance to permethrin, a pyrethroid (Leibee 1981). Hymenopteran parasitoids are very susceptible to broad-spectrum insecticides such as chlorinated hydrocarbons (Baranowski 1958, 1959) and carbamates (Catman and Kennedy 1976, Waddill 1978). If leafminer populations have developed resistance to these compounds, the effects of parasitoid mortality are greatly exacerbated.

Insect growth regulators (IGR's), chemical compounds which disrupt or inhibit normal growth processes, have

recently exhibited promise for Liriomyza control as they are potentially compatible with biological control agents due to their low toxicity, host specificity and nonpersistence in the environment (Parrella et al. 1982). Significant leafminer larval mortality (Parrella et al. 1983a) and sublethal effects on adults exposed as larvae (Robb and Parrella 1984) have been reported for IGR treatments. Trumble (1985) and Parrella et al. (1983a) reported that IGR's did not significantly reduce survival of parasitoids although Trumble found cyromazine significantly reduced abundance of some key parasitoid species in celery.

An extract of seeds from the neem tree, Azadirachta indica A. Juss, has also recently received attention as a broad-spectrum insect antifeedant and pesticide (Webb et al. 1983). Foliar applications reduced L. trifolii oviposition and caused greater than 98% L. trifolii and sativae larval mortality (Webb et al. 1983). Soil applications also reduced survival of L. trifolii larvae and pupae, although oviposition and adult feeding were not inhibited (Knodel-Montz et al. 1985, Larew et al. 1985).

Currently, Florida celery growers, as well as those in California, rely on cyromazine (Trigard®), a larvicide, methamidiphos (Monitor®), a larvicide and adulticide, and permethrin (Ambush®), an adulticide, for Liriomyza control (P.F. Foster, personal communication, 1986). In the Belle Glade area cyromazine is usually applied at 0.125 lb AI per acre once a week during normal infestations while

methamidiphos and permethrin are applied at 1.0 lb and 0.2 lb AI per acre, respectively, as often as two to three times a week (R.E. Foster, personal communication, 1986).

Natural Control by Parasitoids

Parasitoids of various species in several families play an important role in the natural regulation of Liriomyza and other agromyzids (Griffiths 1962, Oatman 1959b). Webster and Parks (1913) presented one of the earliest records of Liriomyza (as Agromyza) parasitoids reporting 28 spp. reared from A. pusilla on alfalfa and other forages with Diglyphus (as Diaulinus) begini (Ashmead) as the most important. Hills and Taylor (1951) reported 10 spp. of parasitoids representing five families of Hymenoptera from Liriomyza spp. on lettuce and cantaloupe with parasitism rates ranging from 0-100%. Oatman (1959b) found 19 spp. representing six families attacking L. pictella in California and noted D. (as Solenotus) begini and Halticoptera aenea (Walker) were the most prevalent species. Harding (1965) reported 21 spp. of parasitoids in four families attacking L. munda on 13 vegetable crops and two weed spp. in the winter garden area of Texas, while Stegmaier (1966a, 1966b) reared five and nine spp. from L. sativae (as munda) and L. trifolii, respectively, in south Florida.

Liriomyza sativae parasitoid complex composition and abundance were reported by Oatman and Kennedy (1976) and Johnson et al. (1980b) for California tomatoes and by McClanahan (1977) for greenhouse beans in Canada. Diglyphus begini, Chrysonotomyia punctiventris (Crawford) and Opius dimidiatus (Ashmead) were the most abundant species reared from host larvae and pupae. Chandler (1982) found eight spp. of parasitoids attacking L. sativae and trifolii on cantaloupe in Texas but noted under optimal environmental conditions leafminer populations increase too rapidly for effective control by parasitoids. Poe and Montz (1981) listed 53 parasitoid spp. from five families reported from four economically important Liriomyza species: L. trifolii, sativae, huidobrensis, and brassicae (Riley). Most parasitoid species (31 in 11 genera) occurred in the family Eulophidae.

In Florida, Genung and Janes (1975) reared several species of parasitoids from both leafminer-infested celery and weeds in the Belle Glade area with parasitism rates as high as 100 and 94% from the weeds dog fennel, Eupatorium capillifolium (Lam.), and water pennywort, Hydrocotyle umbellata L., respectively. Thirty-two percent parasitism occurred on celery. Genung (1981) surveyed important weed hosts in the celery-growing region near Belle Glade and observed parasitism was more prevalent in celery nearest weedy borders. Parasitism rates of ca. 90% were determined for Liriomyza in California celery (Trumble and Nakakihara

1983). Diglyphus intermedius (Girault) and D. begini were the most prevalent parasitoids reared.

Detrimental effects of DDT, methoxychlor, dieldrin, endrin, and lindane on Liriomyza parasitoids were noted by Wene (1955) and by Getzin (1960) for diazinon, parathion, and ethion. Baranowski (1958) stated DDT use was a major factor of ineffective control of Liriomyza in pole beans in south Florida, while Oatman (1959b) noted the same effect of such chlorinated hydrocarbons on parasitoids of Liriomyza in California melons. Methomyl was found to be most injurious to parasitoids in tomatoes while causing increases in L. sativae populations (Johnson et al. 1980a, Oatman and Kennedy 1976). Parasitization by Chrysocharis parksi Crawford was reduced ca. 40% at the lower treatment rate of methomyl (Johnson et al. 1980a). Schuster and Price (1985) found methomyl and permethrin significantly reduced the number of parasitoids reared from treated tomato foliage and leafminer pupae collected from treated foliage. Zehnder and Trumble (1985) also determined permethrin to be most injurious to leafminer parasitoids of six insecticides tested.

Insecticides which increase mortality of leafminers without a similar increase in parasitoid mortality have been studied for incorporation into pest management programs. Trumble and Toscano (1983) found methamidiphos allowed for 50% more parasitism of leafminers in celery than methomyl. Trumble (1985) suppressed leafminer populations in celery

with abamectin (=avermectin), a neural transmission inhibitor , without adversely affecting percent parasitism, adult parasitoid mortality or immature parasitoid survival and emergence. He determined abamectin the most suitable compound of those tested for integration into a pest management program for L. trifolii in celery. Although applied only for lepidopterous larvae control, the biological insecticide Dipel®, Bacillus thuringiensis var. kerstaki, and chlordimeform, a lepidopteran ovicide, proved least injurious to the major leafminer parasitoids D. begini and C. punctiventris when applied in combination to tomatoes (Johnson et al. 1980b).

Effects of Cultural Methods

Polyethylene mulches and staking of tomatoes increased Liriomyza and, consequently, Liriomyza parasitoid incidence. Plants which were both mulched and staked contained greatest leafminer infestations (Price and Poe 1976). Percent parasitism was highest on nonstaked plants. Webb and Smith (1973) found mulched snap beans contained more L. sativae (as L. munda) than nonmulched beans, but aluminum foil mulches apparently repelled Liriomyza spp. in tomatoes and squash (Wolfenbarger and Moore 1968).

Increased fertilization resulted in increased Liriomyza survival (as percentage of mines completed) on chrysanthemums (Poe et al. 1976). Average number of mines per leaf and percent leaves infested did not vary

significantly with fertilization rates. Woltz and Kelsheimer (1958), however, found chrysanthemum with higher levels of nitrogen most heavily damaged by leafminers. Harbaugh et al. (1983) reported L. trifolii damage of chrysanthemum increased linearly as leaf nitrogen increased from 2.2 to 4.0%.

Sanitation in celery (i.e. plowing under of crop debris and weed control) is considered the most effective method of cultural control of leafminers (Guzman et al. 1973), although weeds on field borders harbor many beneficial arthropod species capable of inflicting significant mortality upon Liriomyza (Genung and Janes 1975, Genung 1981). Seedbed clippings, which contained ca. 50% of the seedbed leafminer population, were implicated as sources of reinfestation and a recommendation was made to collect and destroy them (Genung and Janes 1975). Sanitation is also considered important for leafminer control in chrysanthemums (Short and Price 1981).

Postharvest flooding of fields is an important technique in controlling nematodes, soil-borne diseases, weeds and insects in celery (Guzman et al. 1973, Genung 1976). This measure, however, probably does little to decrease leafminer populations in celery except for controlling certain weeds that may serve as hosts of Liriomyza (Joan Dusky, personal communication, 1986).

Pest Management in Celery

In the mid-1970s a pest management program for celery in the Belle Glade area was devised and evaluated utilizing insect, disease, and weed surveys (Genung et al. 1978). A second study emphasized factors pertaining to celery growth and composition and concluded the program "in all cases reduced the use of pesticides, was less expensive, and savings were more than adequate to compensate for scouting" (Guzman et al. 1979).

The current strategy for L. trifolii used by some Belle Glade area growers consists of monitoring fields daily, collecting celery trifoliate samples and estimating fluctuations in leafminer density utilizing the pupal drop count method of Foster (1986). Decisions to treat are not based on economic thresholds but on changes in population levels and effectiveness of prior treatments (R.F. Foster, personal communication, 1986).

Celery Production

In the Everglades region of south Florida celery plants are grown from seed in raised seedbeds containing an irrigation and drainage network. Seedbeds are covered by shading structures from May to October during the first five weeks after seeding when unshaded soil surface temperatures are too hot for seed germination. The tops of seedlings are

trimmed to toughen the lower tissues thus better enabling the plants to withstand the shock of transplanting. Depending on the season, two to eight toppings are made. Seedlings are grown from May until early April and take an average of 70 d to reach transplanting stage (Guzman et al. 1973).

Transplanting of seedlings from seedbed to field occurs from early August to April. Seedlings are pulled and boxed by hand, watered, then transplanted by workers using transplanting equipment. Immediately after transplanting, the celery is overhead-irrigated until water is standing in the field. The water table, manipulated by sub-irrigation, is kept as high as possible before and after transplanting, but after plants have recovered from transplant shock it is maintained at 18 to 20 inches. Harvesting occurs from November to late June with mean time from transplanting to harvest being 90 days (Guzman et al. 1973).

Five varieties constitute practically all the celery grown in the Belle Glade area. Florida 683K strain, the most widely grown, is used for the major crop in mid-winter as it is susceptible to early blight and leafminers and bolts early. June Belle variety, slightly resistant to early blight and not as prone to bolting as 683k during prolonged cold periods at early growth stages, is the second most popular variety and is grown in the late spring. Recently released for early fall plantings, Floribelle (FREC M9 line) has good resistance to early blight, some tolerance

to bacterial leaf spot and some leafminer resistance and is the next most popular variety. Florida Slobolt (EREC M68-29-5), just released for harvest in April and early May, has long ribs and good resistance to early blight, premature seeding and bolting. Once the most widely grown variety, Florida 2-14 is very attractive to leafminers and, therefore, its popularity has declined considerably in the last decade (E.A. Wolf, personal communication, 1986).

Seedbeds and fields are plowed, disked, levelled and flooded. After drying they are plowed, disked, levelled, mole-drained, and fertilized prior to transplanting. The flooding procedure entails four weeks of flooding, two of drying, then four more of flooding which is necessary to insure mortality of the hardiest pests such as wireworms. Soil fumigation of seedbeds and applications of insecticides, herbicides, and fungicides to the crop, in addition to flooding, are required to assure adequate yield. Soil pH is often adjusted with applications of sulfur usually incorporated at the time of fertilization (Guzman et al. 1973).

The first commercial celery planting in Florida made in 1897 at Sanford was 0.75 of an acre and netted $1,300 (Guzman et al. 1973). In 1984-85, 9,300 acres of celery were planted in Florida (7,295 in the Everglades area); 8,600 of these were harvested yielding an average of 665 crates per acre (one crate=60 lbs). Season average monetary value was $6.38 per crate resulting in a total value of

$36,515,000, down from the record value recorded in 1983-84 of $64,546,000 (Anon. 1986).

Beneficial Aspects of Weeds

Weeds are primarily considered competitors of crops for sunlight, water and soil nutrients and often as reservoirs for pestiferous arthropod species and plant pathogens. However, certain ecological and physiological aspects documented in recent decades have proven the beneficial role of certain species and their potential for use through manipulation in pest management systems (Altieri and Whitcomb 1979a).

Ecosystems consisting of many and varied plant species are known to contain a greater variety of insect species (Pimentel 1961, Risch et al. 1983). Consequently, pest mortality due to natural enemies in such systems is often greater than in less diversified ones. Altieri et al. (1978) found 26, 45 and 14% fewer leafhoppers, Empoasca kraemeri Ross and Moore, banded cucumber beetles, Diabrotica balteata Le Conte, and fall armyworms, Spodoptera frugiperda J.E. Smith, respectively, in a bean-corn polyculture than in bean or corn alone. Presence of weeds enhanced predation and/or parasitism of cabbage white butterfly larvae, Pieris rapae (L.), in brussels sprouts (Dempster 1969), fall armyworm in corn (Altieri and Whitcomb 1980) and Mexican

bean beetle, Epilachna varivestis Mulsant, in soybeans (Shelton and Edwards 1983). Predation by fire ants, Solenopsis invicta Buren, in sugar cane was also enhanced (Ali et al. 1984). Risch et al. (1983) noted, however, that herbivore movement patterns may be more important than natural enemy activity in explaining reduction of certain pest populations in diverse annual systems.

Nonpestiferous herbivores on weeds may serve as prey/host sources for beneficials, thus increasing the survival and ,possibly, population levels of these entomophagous species (Altieri and Whitcomb 1979a, Perrin 1975). Surveys by Needham (1948) of Spanish needle, Bidens pilosa L., Stegmaier (1971, 1973) of common ragweed, Ambrosia artemisifolia L., and joe-pye weed, Eupatorium coelestinum L., and Altieri and Whitcomb (1979b) of Mexican tea, Chenopodium ambrosioides L., determined certain weeds can harbor an assortment of arthropod species. A famous example of a natural enemy utilizing alternate hosts on a non-crop plant is that of the leafhopper parasitoid, Anagus epo Girault, which attacks eggs of a nonpestiferous species year round on wild Rubus spp. (Doutt and Nakata 1973). In summer, individuals migrate to grape to parasitize eggs of the grape leafhopper, Erythroneura elegantula Osborn, inflicting severe mortality in early season on this important pest.

Weeds may also serve as sources of amino acids and carbohydrates for beneficials. Syme (1975) determined

longevity of individuals of two parasitoids of the European pine shoot moth, Rhyacionia buoliana (Schiffermueller), increased when feeding on various flowers over that of starved controls. Fecundity of individuals of one species fed flowers increased over those being fed honey. Leius (1967) reported 18 times as many tent caterpillars, Malacosoma americanum (F.), pupae were parasitized in orchards with a rich undergrowth of wildflowers as in those with poor wildflower undergrowth.

Certain non-crop plants are believed to act as pest repellants or inhibitors, thus protecting crops when the two plant species occur together. Flea beetles, Phyllotreta cruciferae Goeze, were significantly less attracted to a combination of collards and common ragweed than collards alone in laboratory experiments (Tahvanainen and Root 1972). Altieri et al. (1977) and Schoonhoven et al. (1981) determined populations of the leafhopper E. kraemeri on beans were decreased by the presence of the grass weeds Leptochloa filiformis (Lam.) and Eleusine indica (L.) Gaertn. The grasses either repelled the pest, inhibited feeding or masked attractive odors of the crop.

Reduction in crop apparency (Feeny 1976) resulting from weed occurrence may also influence pest and natural enemy populations (Perrin and Phillips 1978, Altieri and Whitcomb 1979a). Smith (1969) found larger populations of cabbage aphid, Brevicoryne brassicae (L.), and whitefly, Aleyrodes brassicae (Wlk.), on brussels sprouts in

cultivated plots with bare soil than in plots with a weed cover. These results were confirmed by Horn (1981) working with green peach aphid, Myzus persicae (Sulzer), on collards.

Smith (1976) also discovered certain predators were plant oriented. The syrphids Melanostoma spp.and Platycheirus spp. and an anthocorid, Anthocoris sp., were apparently attracted to weedy plots for oviposition. A prey-oriented syrphid, Syrphus balteatus DeGeer, was attracted to brussels sprouts which harbored more aphids.

Surveys of weed hosts of Liriomyza spp. have been conducted (Harding 1965, Stegmaier 1966a, 1966b, Spencer 1981a), but few studies have attempted to assess the impact these alternate hosts have on vegetable agroecosystems. Schuster et al. (1982) found downy groundcherry, Physalis pubescens L. (reported as groundcherry, P. angulata L.), American black nightshade, Solanum americanum Mill. (reported as black nightshade, S. nigrum L.) and common beggartick, Bidens alba (L.) (reported as Spanish needle, Bidens spp.), the most important weed hosts of Liriomyza adjacent to tomato fields. Over 80% parasitism was found for mines collected from these and other weeds of the tomato field borders surveyed.

Zoebisch (1984) studied the suitability of the three weed species mentioned above and tomato as hosts for tomato- and weed-reared L. trifolii in the laboratory. American black nightshade proved the most suitable of the weed hosts

as tomato-reared females preferred it and tomato as oviposition substrates and fecundity was greatest on these two hosts.

Genung and Janes (1975) found 22 plant species, most of them composites, as important weed hosts of L. trifolii in the celery agroecosystem near Belle Glade. Parasitism rates greater than 90% occurred on four species of weeds surveyed. Although potential sources of pestiferous arthropods, virus infection, and infield weed infestation, Genung (1981) stated "weedy marginal and interior ditch banks in celery fields are more beneficial, through actual conservation of parasites and predators of leafminers and other insects, than detrimental" (p.68).

Description, History and Status of Castorbean

Castor bean, Ricinus communis L., is a member of the family Euphorbiaceae, commonly called the spurge family, predominantly indigenous to the tropics. Castor bean is the only species of Ricinus, but it includes many polymorphic types ranging from large perennials resembling small trees to short-lived dwarf annuals. The erect, partially hollow stem is marked by well-defined nodes from each of which a leaf arises. Leaves are glossy green, large-bladed, and palmate with five to 11 lobes. Flowers are normally monoecious appearing terminally on main and lateral

branches. The fruit is roundish, three-sided, covered with spines, and divided into three loculi. Seeds, one to a locule, are broad, oval, compressed, of variegated color, oleaginous, and very poisonous (Weiss 1971).

Domesticated in prehistoric times, castor bean is considered Ethiopean in origin. Oil extracted from the seeds was used as lamp oil, for annointments, as a medicine acting as a purgative and as a lubricant. Seeds were an important item of commerce in ancient Egypt and their uses have appeared in ancient Greek, Roman, Indian, Hebrew and Chinese writings. First introduced into England in 1548, castor bean probably entered the New World with the slave trade (Weiss 1971).

Today, oil from the seed is used primarily in resins, plastics, paint, and varnishes (Weiss 1971). World seed production for the 1984-5 season was one million metric tons with India the largest producer (385,000 metric tons). The Soviet Union, West Germany, the Netherlands, France, Great Britain and the United States are the major importers (Emery 1985).

Production in the U.S. is negligible and virtually all castor bean appears growing wild. Occurring predominantly on canal and ditchbanks, castor bean is not considered a major weed of crops in south Florida. Genung and Janes (1975), however, considered it a major weed host of L. trifolii and, consequently, its parasitoids in the Belle Glade area. Greater than 85% parasitism of the pest on

castor bean occurred at each of two locations. Stegmaier (1981), however, reported castor bean as a host of L. sativae and not trifolii. He also mentioned finding a castor bean leaf containing 80 L. sativae mines on two separate occasions, illustrating the breeding potential of this species on an alternate, wild host.

CHAPTER III
LEAFMINER AND LEAFMINER PARASITOID INCIDENCE ON SELECTED WEEDS IN SOUTH FLORIDA

Introduction

Although the leafminer Liriomyza sativae (Blanchard) was considered a pest of celery in Florida (Musgrave et al. 1975b, Poe and Montz 1981), L. trifolii (Burgess) is currently the major, if not only Liriomyza spp. affecting this crop (Stegmaier 1981, Leibee 1984). Both species are attacked by the same parasitoid complex (Chandler 1982); therefore, a weed species serving as a host of L. sativae could act as a reservoir for these natural enemies and thus, possibly enhance biological control of L. trifolii within nearby celery fields.

The ability of weeds to harbor beneficial arthropod species has been studied and discussed by several authors: Doutt and Nakata (1973), Perrin (1975), Altieri et al. (1977), Altieri and Whitcomb (1979a,1979b) and Shelton and Edwards (1983), to name a few. Influence of weeds on leafminer mortality in south Florida was noted by Genung and Janes (1975) and Genung et al. (1978), who reported parasitism rates of Liriomyza were higher on borders of celery fields adjacent to weeds. Such observations justify

investigations into the potential of certain native weed species as reservoirs for parasitoids.

Of the 80 hosts reported by Stegmaier (1981) for L. trifolii and sativae, 29 were attacked by the latter only. Although found in south Florida, not all occur in the celery-growing region near Belle Glade and fewer still in sufficient numbers to warrant their study. Two weed species, sicklepod, Cassia tora L. , a legume, and castor bean, Ricinus communis L., a euphorb, were reported by Stegmaier (1981) as hosts of L. sativae only and are commonly found in south Florida. These characteristics, plus the fact seeds of the two species are readily obtainable, make them amenable to study. Dayflower, Commelina diffusa Burm., of the family Commelinaceae, was also chosen for study. Although not attacked by either L. sativae or trifolii, it is attacked by a similar species, L. commelinae (Spencer and Stegmaier 1973), which may have parasitoids in common with L. trifolii. Also, dayflower is very common in the Everglades region and cuttings for transplanting are easily obtainable. L. commelinae is reported to attack only plants of the genus Commelina (Stegmaier 1966c).

The objectives of this study were to 1) determine the abundance of L. sativae and possibly other leafminer species on these three weeds, 2) monitor the abundance and species composition of the parasitoids of these pests and 3)

ascertain leafminer and parasitoid occurrence and abundance for a year on the weed species most preferred by Liriomyza.

Methods and Materials

Host Preference Study

Test plots of castor bean, sicklepod and dayflower were planted February 24, 1984 at two sites at the Everglades Research and Education Center (EREC) two miles east of Belle Glade. Plots consisted of five rows 3 m long and 3 m wide planted on 0.75 m centers. There were three replications arranged in randomized complete block designs at each site. Alleyways between plots were 1.5 m wide. Castor bean and sicklepod were established from seed while dayflower was transplanted using cuttings taken from EREC. Plantings of castor bean and sicklepod were thinned to ca. 10 plants per row while dayflower was allowed to cover the entire plot.

Sampling began in late May when leafminer infestations were first noticeable. One leaf of castor bean and one trifoliate of sicklepod were randomly selected from each of three canopy layers (top, middle and bottom) of 10 randomly selected plants per plot. Dayflower, a prostrate plant, was sampled by collecting all foliage from 10 randomly selected 18 cm x 18 cm areas within a plot. Foliage was placed in plastic bags to minimize dessication during transport to the laboratory.

Active mines (containing living leafminer larvae) and old mines (those from which leafminers or their parasitoids had already exited) were counted from all samples. Mines containing larvae which appeared dead were considered old. Foliage containing active mines was placed on wire screen in closed cardboard containers to allow for emergence of parasitoid adults and mature leafminer larvae. Containers were held at 24.0 $\pm$ 5.5^{o} C and 65 $\pm$ 15% RH. Larval parasitoid adults and leafminer puparia were collected after foliage had dried (ca. 5 d). Puparia were held in glass vials until all leafminer and larval-pupal parasitoid adults had emerged and died. Adults were identified and counted.

Prior to placing foliage in cardboard containers, foliage was subsampled to determine leaf surface area. One half of the castor bean leaves and sicklepod trifoliates from each canopy layer and one half of the dayflower samples were randomly selected and leaf area measured using a LICOR® areameter. Also, plant height and number of leaves per plant were determined for 10 randomly selected plants from each castor bean and sicklepod plot for every sampling period. Sampling was conducted ca. once weekly for eight weeks ending the third week of July, 1984.

Seasonal Abundance

Sampling of castor bean to determine seasonal variations in leafminer and parasitoid populations and percent parasitism was conducted for one year beginning August 8, 1984. Plots utilized in the prior study were

examined biweekly, except in a few cases when they were sampled once in three weeks. All foliage containing active mines was collected and held in the same manner and under the same conditions as in the previous study. All leafminer and parasitoid adults reared from foliage were identified and counted.

Representative specimens of parasitoid species collected in this and the prior study were identified by E.E. Grissell, A.S. Menke and M.E. Schauff, Systematic Entomology Laboratory, USDA, Washington, D.C., R.A. Wharton, Department of Entomology, Texas A&M Universty, College Station, Texas and C.M. Yoshimoto, Department of Environment, Canadian Forestry Service, Ottawa, Ontario, Canada.

Results and Discussion

Host Preference Study

Leafminer occurrence on sicklepod and dayflower during the sampling period was slight. Of 87 mines found on sicklepod foliage only two contained living larvae. Neither larva developed to pupation. Although no adult leafminers were reared from sicklepod, most, if not all, mines may have been those of Liriomyza since they were serpentine in appearance and the majority of them (62%) occurred during the first two weeks of sampling when Liriomyza was most abundant on castorbean. Thus, damage inflicted upon these two plant species, particularly during this time, may have

been caused by the same leafminer infestation (i.e. species).

Only 15 mines were collected from dayflower; four were active and one L. commelinae adult and one pupal parasitoid were reared from them. The parasitoid was a Cynipid, possibly of the genus Ganaspidium, as it was very similar, if not the same, as that reared from Liriomyza on castor bean. The specimen, however, was not sent for identification. Stegmaier (1966c) reared only one parasitoid from L. commelinae in south Florida, Chrysocharis majoriana (Girault), a neotropical eulophid. If the cynipid reared is the same as that attacking L. trifolii, dayflower may be considered beneficiial in that it harbors a natural enemy of the pest.

Genung (1981) found dayflower to contain significantly more chalcidoid parasitoids than other weeds (e.g. Spanish needle, Bidens pilosa L., Virginia pepperweed, Lepidium virginicum L., spiny amaranth, Amaranthus spinosus L. and others) sampled near celery fields with sticky traps. Flower nectar, however, rather than the presence of leafminer larvae is believed the major attractant of these parasitoids to dayflower (G.L. Leibee, personal communication, 1986).

Liriomyza populations on castor bean were much greater than those on sicklepod or dayflower. Populations peaked the first week of sampling with more than 22 active mines collected per 5000 sq. cm leaf surface area (Figure 3.1).

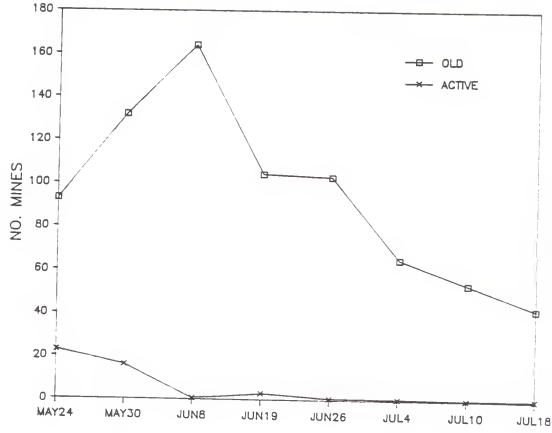

Figure 3.1 Mean number of old and active mines of L. sativae and L. trifolii collected per 5000 sq. cm of castor bean foliage, Belle Glade, FL (1984).

Active mine density decreased significantly ($P<0.05$) after the second sampling period and, except for a slight increase during the fourth sampling period, were less than one active mine per 5000 sq. cm.

As leafminers continued to attack castor bean, old mines continued to accumulate and did not peak until the third sampling period at greater than 162 mines per 5000 sq. cm (Figure 3.1). The almost complete cessation of leafminer activity and subsequent senescence of lower leaves decreased foliage area containing old mines. Although not an indicator of present infestation levels, old mines can be used to determine the extent of recent leafminer attacks and the potential of plant species as hosts in the future.

All leafminer adults reared from castor bean foliage were either L. sativae or L. trifolii with the former comprising 63.3% of the specimens. More than 4.2 adult Liriomyza per 5000 sq. cm of foliage were reared during the first week of sampling (Figure 3.2) but numbers declined steadily with the decrease in active mines. No L. trifolii were reared after May 30 and L. sativae was collected only twice (weeks of June 19 and July 18) during the same period.

The disparity between number of active mines collected and adults reared from these mines resulted in part from the dessication of foliage within cardboard rearing containers. Larvae collected as first and early to mid-second instars probably lacked sufficient time to complete development although foliage, when held in adequate amounts, remained

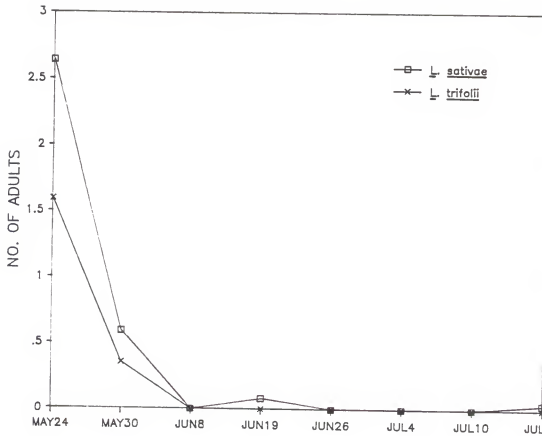

Figure 3.2. Mean number of L. sativae and L. trifolii reared per 5000 sq. cm of castor bean foliage collected, Belle Glade, FL (1984).

relatively moist several days after sampling. Tryon (1979) found that fewer celery trifoliates per rearing container resulted in accelerated dessication and fewer adults reared per trifoliate. Filling containers three quarters full with castor bean leaves was normally sufficient for rearing adequate numbers of adults. Completely filling a container usually promoted leaf tissue decay resulting in death of developing leafminers and parasitoids.

High levels of parasitism also accounted for reduced leafminer emergence. More than 9.6 adult parasitoids per 5000 sq. cm were reared from Liriomyza collected during the first sampling period (Figure 3.3). The majority of parasitoids (9.5) were larval-pupal species in which females parasitize the larvae and adults emerge from the puparia. Although larval parasitoid (i.e. those that utilize only the larval stage for development) incidence increased during the week of May 30, the total number of parasitoids decreased corresponding with the decrease in leafminers. Levels never exceeded 0.65 per 5000 sq. cm for the remainder of the study.

Eleven species of parasitoids representing four families of Hymenoptera were reared from Liriomyza on castor bean (Table 3.1). All braconids plus Halticoptera circulus (Walker), Chrysocharis parksi Crawford and Canaspidium sp. are larval-pupal parasitoids while the remaining are larval parasitoids. Larval-pupal species accounted for over 82.0% of all parasitoids reared for the entire sampling period

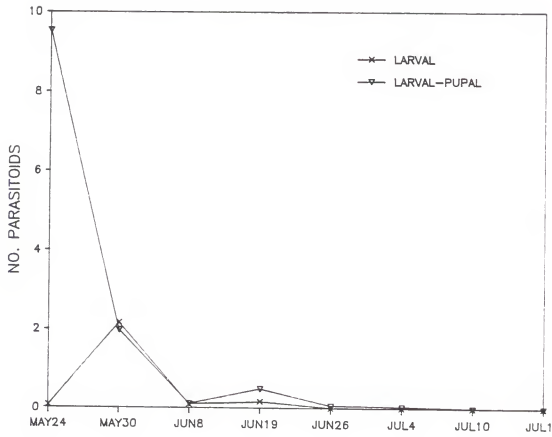

Figure 3.3. Mean number of adult parasitoids reared per 5000 sq. cm foliage collected from L. sativae and L. trifolii on castor bean, Belle Glade, FL (1984).

Table 3.1. Hymenopteran parasitoid species reared from L. trifolii and L. sativae on castor bean in Belle Glade, FL (May-July 1984).

Family	Species	Abundance (%)
Braconidae	Opius dimidiatus (Ashmead)	31.8
	O. dissitus Muesebeck	21.2
	O. bruneipes Gahan	2.1
	Oenonogastra microrhophalae (Ashmead)	4.2
Eulophidae	Diglyphus intermedius (Girault)	8.7
	Chrysonotomyia punctiventris (Crawford)	5.3
	Chrysocharis parksi Crawford	2.1
	Closterocerus sp.	1.8
	Pnigalio flavipes (Ashmead)	1.8
Pteromalidae	Halticoptera circulus (Walker)	20.6
Cynipidae	Canaspidium sp.	0.3

with species in the genus Opius the most prevalent (Table 3.1). Opius spp. also accounted for the majority of adult parasitoids emerging from weed foliage adjacent to tomato fields in central western Florida (Schuster et al. 1982).

Percent parasitism, calculated by dividing the number of adult parasitoids reared from foliage by the number of adult leafminers plus parasitoids reared, was 100% for larval and larval-pupal parasitism combined for the third, fifth and sixth sampling dates (Figure 3.4) when only eleven, three, and two parasitoids, respectively, were collected. (No leafminer or parasitoid adults were reared the week of July 10 and this is represented by 0% parasitism.) Genung et al. (1978) found over 90% parasitism of mines occurring on castor bean in the Belle Glade area. O. dimidiatus accounted for all parasitism the fifth and sixth sampling dates while only two L. sativae were collected during the final sampling period when no parasitism occurred.

All parasitoids in general and Opius spp. in particular apparently exhibited exceptional searching ability, attacking the majority, and sometimes all, leafminer larvae collected and reared even when populations were extremely low. Parasitism rates for the four most prevalent species are presented in Table 3.2. Mortality due to the majority of larval-pupal parasitoids appears to be density independent, (i.e. its effect does not vary with the occurrence or population density of the species regulated

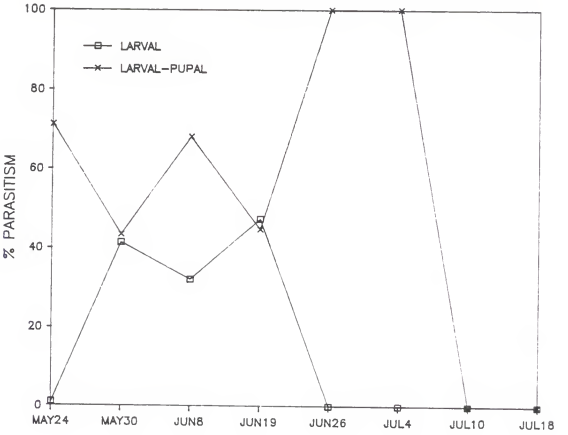

Figure 3.4. Mean percent parasitism of L. sativae and L. trifolii on castor bean by larval and larval-pupal parasitoids, Belle Glade, FL (1984).

Table 3.2. Mean percent parasitism of L. trifolii and L. sativae on castor bean by the four most prevalent species of parasitoids, Belle Glade, FL (1984).

Date	n	O. dimidiatus	O. dissitus	H. circulus	D. intermedius
May24	567	33.8a	18.6ab	12.6a	1.0a
May30	220	27.3a	9.4ab	1.9b	23.1a
Jun 8	11	30.1a	34.0a	0.0b	14.0a
Jun19	33	19.3a	16.4ab	6.7ab	14.3a
Jun26	4	100.0b	0.0b	0.0b	0.0a
Jul 4	2	100.0b	0.0b	0.0b	0.0a
Jul10	0	--	--	--	--
Jul18	2	0.0a	0.0b	0.0b	0.0a

Means in columns followed by same letter not significantly different by Duncan's new multiple range test ($P<0.05$). Data transformed by arcsine ($\sqrt{x}$) transformation before analysis; untransformed data presented.

(van den Bosch et al. 1982)) since percent parasitism due to these species remains relatively high despite changes in leafminer density. Larval parasitoids, however, perhaps exhibited a delayed density dependence, first inflicting significant mortality a week after Liriomyza populations had peaked and becoming relatively ineffective as leafminer densities decreased.

Liriomyza adults apparently preferred to oviposit on castor bean foliage occupying the mid-canopy region (Table 3.3) which, for the first two sampling periods when the majority of active larvae were collected, was ca. 55-130 cm above the ground. Mean plant heights were 166.2 and 191.4 cm for periods one and two (Figure 3.5), respectively. The mid-canopy regions, calculated as the middle third of these heights, were ca. 55-110 and 64-128 cm for the two periods.

Most adult parasitoids were also reared from mid-canopy foliage (Table 3.4) which was to be expected as most leafminers occurred there. Larval parasitoids, however, apparently exhibited a preference, although not significant, for hosts in the lower canopy. These species, all small eulophids, may be more effective nearer the ground where lower wind speeds may allow for a more stable environment in which to search for hosts. Percent parasitism was significantly greater in the bottom canopy layer for larval parasitoids (Table 3.5) again demonstrating the lower canopy's possible enhancement of efficient host-finding for these smaller species. In contrast, larval-pupal

Table 3.3. Mean number of old and active mines collected and L. trifolii and L. sativae adults reared per 5000 sq. cm of castor bean foliage, Belle Glade, FL (May-July 1984).

Canopy layer	Old	Active	L. trifolii	L. sativae
Top	2.5a	0.5a	<0.1a	<0.1a
Middle	122.5b	12.8b	0.6b	1.1b
Bottom	158.6c	3.5a	0.1a	0.2a

Means in columns followed by same letter not significantly different by Duncan's new multiple range test (P<0.05).

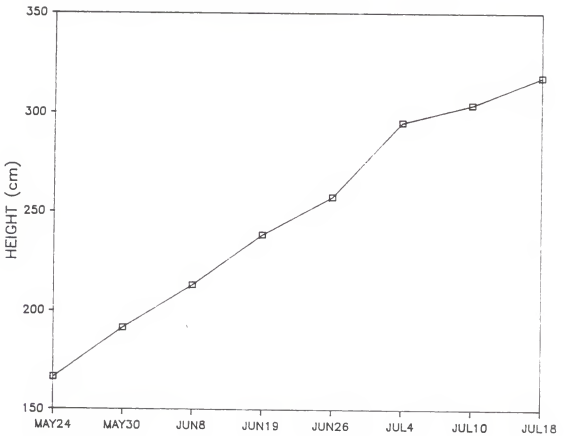

Figure 3.5. Mean growth of castor bean at EREC, Belle Glade, FL (1984).

Table 3.4. Mean number of total, larval and larval-pupal parasitoids reared per 5000 sq. cm foliage from L. trifolii and L. sativae on castor bean, Belle Glade, FL (May-July 1984).

Canopy layer	Total	Larval	Larval-Pupal
Top	0.07a	0.01a	0.06a
Middle	4.19b	0.38ab	3.82b
Bottom	1.24a	0.54b	0.70a

Means in columns followed by same letter not significantly different by Duncan's new multiple range test ($P<0.05$).

Table 3.5. Mean percent total, larval and larval-pupal parasitism of L. trifolii and L. sativae on castor bean, Belle Glade, FL (May-July 1984).

Canopy layer	Total	Larval	Larval-pupal
Top	65.2a	18.7a	46.4a
Middle	78.8ab	11.2a	67.5a
Bottom	93.4b	54.5b	38.9a

Means in columns followed by same letter not significantly different by Duncan's new multiple range test ($P<0.05$). Data transformed before analysis by arcsine ($\sqrt{x}$) transformation; untransformed data presented.

parasitoids, most several times the size of the aforementioned species, performed equally well within all canopy layers.

Seasonal Abundance

Leafminer occurrence on castor bean was negligible for the remainder of the summer of 1984 as populations never exceeded one mine per plot (Figure 3.6). From September 9 to November 4, no mines were found in castor bean foliage; however, populations increased slightly from late November until mid-January when several frosts destroyed all foliage. Regrowth appeared by early March and populations increased rapidly to peaks of greater than 36 and 37 mines on March 25 and April 22, respectively. Leafminer density decreased steadily from early May until the end of sampling.

Parasitoids possibly regulate Liriomyza numbers in late spring and early summer. Increased temperatures and rainfall of mid- to late summer may inflict mortality by increasing incidence of fungal diseases of larvae and pupae. Muck soils like those of the Belle Glade region can stay moist for days during this season and drowning of newly exited larvae and pupae may possibly occur. Charlton and Allen (1981) found submergence in water for 50 h caused 96% mortality of L. trifolii pupae.

L. sativae comprised 74.5% of Liriomyza adults reared from foliage (Figure 3.6) and only once (March 12) did L. trifolii adults reared exceed those of L. sativae. Although

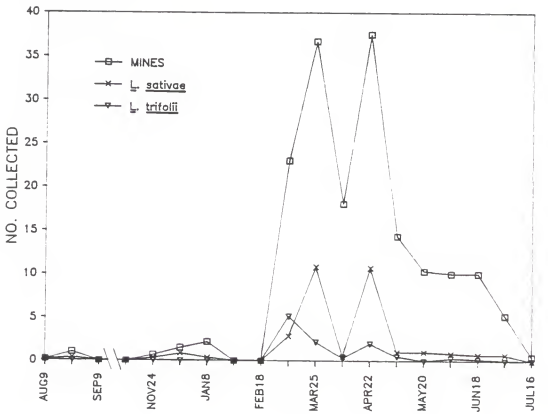

Figure 3.6. Mean number of mines collected and Liriomyza adults reared per 3 m x 3 m plot of castor bean, Belle Glade, FL (1984-85).

Liriomyza was most abundant at approximately the same times for both the host preference study and this study, population densities encountered during the latter were extremely low compared with those of the former study. Foliage during the host preference study was younger with a thinner epidermis and may have been more suitable as an oviposition substrate. Also, ricin, the proteinaceous toxin found in all plant parts, may accumulate as the plant ages, thus possibly decreasing the plants' attractiveness to ovipositing females and/or increasing mortality of eggs and/or young larvae.

Again, larval-pupal parasitoid species comprised the majority (96.3%) of parasitoids attacking Liriomyza (Table 3.6). C. parksi was reared in the previous study but was not reared from foliage in this experiment.

Abundance of parasitoids (Figure 3.7) closely followed that of leafminer hosts. Larval-pupal parasitoid density followed that of Liriomyza, while larval parasitoids occurred at relatively low, but steady levels. This contradicts the observation from the previous study that these species were more density dependent than larval-pupal species. Percent parasitism peaked at 94.8% on April 8 and 100% on July 16 (Figure 3.8), although the percentage for the latter date represents the occurrence of only one individual. Larval-pupal parasitoids accounted for all species reared on these two dates.

Table 3.6. Hymenopteran parasitoid species reared from *Liriomyza trifolii* and *L. sativae* on castor bean, Belle Glade, FL (Aug 1984-July 1985).

Family	Species	Abundance (%)
Braconidae	*Opius dimidiatus*	47.7
	O. dissitus	29.4
	O. bruneipes	2.1
	Oenonogastra microrhophalae	6.1
Eulophidae	*Diglyphus intermedius*	1.5
	Chrysonotomyia punctiventris	1.1
	Closterocerus sp.	0.8
	Pnigalio flavipes	0.4
Pteromalidae	*Halticoptera circulus*	9.7
Cynipidae	*Ganaspidium* sp.	1.3

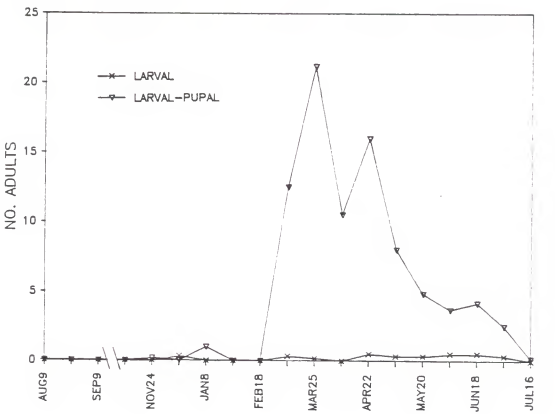

Figure 3.7. Mean number of larval and larval-pupal adult parasitoids reared per 3 m x 3 m plot from L. sativae and L. trifolii on castor bean, Belle Glade, FL (1984-85).

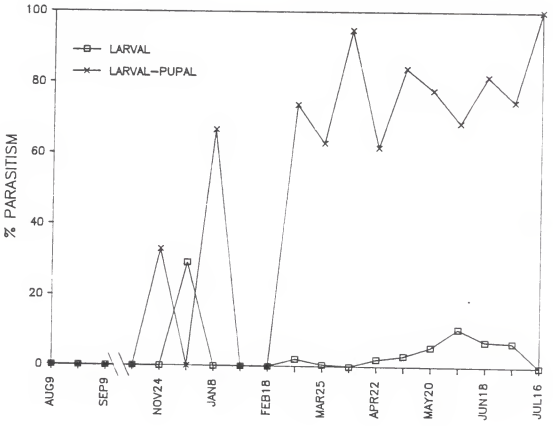

Figure 3.8. Mean percent larval and larval-pupal parasitism of L. sativae and L. trifolii on castor bean, Belle Glade, FL (1984-85).

Results indicate castor bean, particularly young plants, can harbor considerable numbers of Liriomyza and their parasitoids. The high incidence of parasitism imparts a beneficial aspect to castor bean as part of the celery agroecosystem as it probably serves as a reservoir for these natural enemies; however the occurrence of the pest L. trifolii may negate any positive effects of the weed. Considering the report of Stegmaier (1981), the abundance of L. trifolii on this host plant is surprising although Genung and Janes (1975) believed it to be the species attacking castor bean during their study and Spencer (1985) found it on the same host in Kenya.

The extent to which castor bean can affect leafminer and parasitoid occurrence is uncertain. Based on this study and reports of others on the "edge" effects of weeds on Liriomyza and parasitoid incidence in celery (Genung et al. 1978, Genung 1981), the plant probably does play a role in pest abundance and regulation under certain circumstances. Only further studies examining this specific phenomenon can begin to elucidate this weed's impact within celery.

CHAPTER IV
EFFECTS OF CASTOR BEAN ON LEAFMINER AND LEAFMINER PARASITOID POPULATIONS IN ADJACENT CELERY

Introduction

The leafminer Liriomyza trifolii (Burgess) is considered the major insect pest of celery in south Florida (Guzman et al. 1973). It is highly polyphagous attacking over 140 host plants in 32 families worldwide (Patel 1986). The capacity of these hosts, many of which are considered weeds, to affect the population dynamics of L. trifolii and its parasitoids is potentially considerable (Genung and Janes 1975, Genung et al. 1978).

Weeds adjacent to celery and tomato fields are known to act as reservoirs for leafminers and their natural enemies in Florida (Genung 1981, Schuster et al. 1982). Increased rates of parasitism have been reported for celery at field borders nearest weeds (Genung and Janes 1975, Genung et al. 1978). No experiments have been conducted to attempt to quantify the effect weeds have on leafminer and parasitoid population numbers in adjacent celery. Such knowledge may enable growers to utilize insecticides and herbicides more effectively and efficiently and perhaps increase leafminer mortality in celery by manipulating weed species harboring natural enemies.

Detection and quantification of movement of leafminers and parasitoids from weeds to adjacent celery could be inferred from data obtained by sampling celery nearest the weeds and at set intervals into the field. However, another method is required to detect and analyze these phenomena conclusively. If leafminers and parasitoids could be marked via the weed host and if such marked insects and/or their progeny could be collected in adjacent celery, the origin of these individuals could not be questioned. Radioactive isotopes are ideal labels for such a study.

Radioactive isotopes have been used as markers or labels in studies to estimate population numbers, dispersal and mortality factors and study behavior and other aspects of the biology of various organisms. They are relatively easy to apply and detect and, when utilized correctly, do not affect normal behavior of labelled individuals (Southwood 1978). The incorporation of isotopes into host plants has been used to label lepidopterous larvae on deadnettle, Lamium spp., (Cook and Kettlewell 1960) and balsam fir, Abies balsamea L., (Krall and Simmons 1977) and the mirid Orthotylus virescens (Douglas and Scott) on broom, Sarothamous scoparius (L.) (Lewis and Waloff 1964). The radionuclide of phosphorous, ^{32}P, has been the most widely used isotope; however, ^{35}S, due to its longer half life (87 d vs 14.2 d for ^{32}P), is better suited for a study conducted over several weeks.

The purpose of this study was to determine if castor bean (Picinus communis L.), a major weed host of L. trifolii and sativae, contributes to the occurrence of L. trifolii in celery and if parasitoids attacking both leafminer species in castor bean disperse and attack L. trifolii in celery. Celery transplanted adjacent to ^{35}S labelled castor bean in the field was sampled with the goal of collecting labelled individuals. Ovipositional preference of L. trifolii and L. sativae females for castor bean and celery was quantified in a laboratory study.

Methods and Materials

Migration Study

Ten day-old castor bean seedlings were labelled by placing them in aluminum trays containing the isotope ^{35}S in Hoagland's solution at 0.1 microcurie/ml. The bare root systems were placed within the solution and plants were held upright by 2.54 cm diameter chicken wire covering the tops of the trays. Girdling of seedlings by wire was prevented by ringing stems with cotton. Thirty plants were placed in each tray and trays contained 300 microcuries of ^{35}S each. Seedlings were held in this manner for 72 h. A preliminary autoradiography study determined 72 h was adequate time for uptake and translocation of the isotope to all seedling parts.

Seedling roots were washed twice in a magnesium sulfate and water mixture (.0083 M $MgSO_4$ = 1 g/l) to remove the isotope-containing solution from the plants' outer surfaces. The plants were then transplanted to two field sites at EREC in two 50 plant rows spread 0.5 m apart and 25 m in length. Four days later, celery was transplanted at each site in two plots, one on either side and adjacent to the labelled plants. Plots, which were approximately three meters from the castor bean, were 18.5 m in length and 20 m wide at site one and 26 m in length and 15 m wide at site two. Sampling in celery began 12 d after transplanting. This was approximately one week after mines began appearing in the labelled castor bean plants.

Two trifoliates were randomly selected from each of two sites along the two rows closest to the castor bean and from rows every five meters away from the castor bean thereafter. Therefore, trifoliates were sampled at four distances from castor bean at site one (3, 8, 13 and 18 m) and six distances (3, 8, 13, 18, 23 and 28 m) at site two. Collected trifoliates were placed in 0.47 l cardboard rearing containers and held at 25 $\pm$ 3° C and 65 $\pm$ 10% RH until all leafminer and parasitoid adults had emerged and died (ca. two weeks). Adults were identified, counted and examined by autoradiography and liquid scintillation analysis for possible incorporation of ^{35}S. Sampling was conducted weekly for 10 weeks from April 18 to June 20.

Adults were examined for isotope uptake by attaching dead individuals to blotter paper with clear finger nail polish. Blotter paper was taped to 17.5 cm x 12.5 cm Kodak X-omat® AR x-ray film so that specimens were in direct contact with the film. Blotter paper with specimens and film were placed in light-tight wooden boxes which were placed in an ultra-cold freezer at ca. -75° C for 16-20 d. Then the film was developed and examined for darkened areas where individuals were in contact with film signifying occurrence of the isotope. All handling of film prior to development was conducted in a darkroom under red light.

Adult leafminers and parasitoids were also sampled in celery using 7.6 x 12.7 cm Tangle Foot® -coated yellow cards stapled to the tops of 30.5 cm stakes. These sticky traps were placed in the field on the same rows from which trifoliates were sampled. Two traps were placed in each row. Adults collected were identified and counted, then cleaned of Tangle Foot® with alcohol and examined for isotope incorporation in the same manner as those reared from trifoliates. Sticky trap sampling was conducted concurrently with trifoliate sampling.

Selected adult leafminers and parasitoids reared from trifoliates and collected on sticky traps were also examined for containment of the isotope by liquid scintillation analysis. Specimens were placed in a standard fluor cocktail solution for counting with a Tracor® Analytic,

Delta 300 Series liquid scintillation counter. Counts were made at the University of Florida campus, Gainesville.

Host Preference

To determine L. trifolii and L. sativae female preference for castor bean and celery as oviposition substrates, four females and two males (3-4 d old) of one species were placed in 66 cm high x 36 cm wide x 36 cm deep wooden, screened cages containing two castor bean and two celery seedlings each. After 48 h, the flies were removed and plants were monitored for leafmine development. When resulting larvae had matured to mid-third instars (approximately 9-12 d after exposure), infested foliage was excised and placed in petri dishes containing moist filter paper to allow for emergence and pupation of mature larvae. Puparia were collected into small plastic cups where adults emerged and died. Numbers of larvae, puparia and adults produced per cage were noted and recorded. This procedure was replicated 15 times for L. sativae and 16 times for L. trifolii and was conducted at 25 $\pm$ 3^{o} C, 65 $\pm$ 10% RH and a photoperiod of L:D 14:10.

Results and Discussion

Migration Study

No adult leafminers and parasitoids reared from foliage or trapped on sticky traps within celery during the entire sampling period were found to contain the radioactive isotope by either autoradiography or liquid scintillation counting. Yellow sticky traps are considered a reliable method for immediate detection of leafminer adults (Tryon et al. 1980, Musgrave et al. 1975a). If adults are moving into the celery after developing in isotope-containing castor bean some of these labelled individuals should have been collected in the traps. Also, any progeny of these adults which developed in and were reared from celery should contain detectable traces of ^{35}S within body tissues (E.L. Cromroy, personal communication, 1985).

Although the initial results possibly indicate no migration of leafminers and parasitoids from castor bean to celery, another conclusion is possible. The isotope may have dispersed within the castor bean and became too diluted for developing leafminers and parasitoids to incorporate in detectable amounts. Preliminary autoradiography analysis found ^{35}S was absorbed and distributed to all plant parts and L. sativae adults reared from labelled plants shortly after isotope exposure contained detectable amounts of the element. Mines were first noticeable in the transplanted castor bean more than two and one half weeks after

labelling. Therefore, these larvae were exposed to the isotope at least ca. two weeks after labelling. Given the extraordinary growth rate of castor bean (Chapter Three), the ^{35}S may have dispersed throughout plant tissues to concentrations too low to be incorporated into developing individuals and/or to be detected. Liquid scintillation counts of leafminer and parasitoid adults reared from labelled castor bean foliage collected May 7 and May 29 from site two indicated no occurrence of ^{35}S within insect tissues. Despite these findings, some of the collection data suggest castor bean perhaps does affect leafminer and parasitoid population numbers in adjacent celery.

Liriomyza trifolii was the only Liriomyza species reared from celery foliage during the entire ten weeks of sampling. Although L. sativae was reported as a pest of celery in Florida until the late 1970s, L. trifolii is now considered the predominant, if not only, Liriomyza species attacking celery in this region (Leibee 1984). However, both species have recently been reported on the crop in California (Trumble and Nakakihara 1983, Zehnder and Trumble 1984).

Greatest number of adults reared per two trifoliates (11.8) occurred on May 15 (Figure 4.1). Poe et al. (1978) reported rearing 17.2 to 114.5 adult L. sativae per 10 trifoliates from control (untreated) celery plots near Belle Glade. In California Zehnder and Trumble (1984) reared 4.1

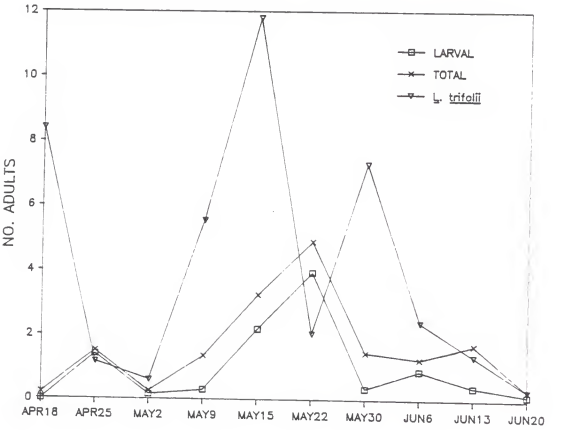

Figure 4.1. Mean number of L. trifolii and total and larval parasitoids reared per two trifoliates of celery adjacent to castor bean, from two sites at Belle Glade, FL (1985).

L. trifolii per two trifoliates of celery while Trumble and Nakakihara (1983) reared 3.6 L. trifolii and sativae adults per two trifoliates.

The number of parasitoids reared from foliage followed closely those of L. trifolii, peaking one or two weeks after those of their host (Figure 4.1). Larval parasitoids of the family Eulophidae constituted the majority of species collected (Table 4.1) in contrast to results of rearings from Liriomyza on castor bean (Chapter Three) where the braconid larval-pupal parasitoids predominated. (Percent abundance of Cenonogastra microrhophalae (Ashmead) appears as a portion of that for Opius dimidiatus (Ashmead). Morphological characters used to distinguish between these two species were obscured by autoradiography and liquid scintillation analyses techniques. Species determinations were not made until after these analyses were conducted.)

Diglyphus intermedius (Girault) and Chrysonotomyia punctiventris (Crawford) were the most abundant species reared from L. trifolii in celery. Members of these genera have previously been reported as the most numerous parasitoids from celery foliage in Florida and California (Tryon and Poe 1981, Trumble and Nakakihara 1983).

Mean number of L. trifolii and parasitoid adults reared per two trifoliates sampled at set distances from the castor bean do not indicate that the weed influenced population numbers in celery (Table 4.2). Although L. trifolii collection results indicate perhaps infestations

Table 4.1. Hymenopteran parasitoid species reared from L. trifolii on celery adjacent to castor bean, from two sites at Belle Glade, FL, 1985.

Family	Species	Abundance (%)
Braconidae *	Opius dimidiatus (Ashmead)	17.0
	O. dissitus Muesebeck	14.6
	O. bruneipes Gahan	7.1
Eulophidae	Diglyphus intermedius (Girault)	42.7
	Chrysonotomyia punctiventris (Crawford)	17.6
	Chrysocharis parksi Crawford	0.3
Pteromalidae	Halticoptera circulus (Walker)	0.6

* Abundance of Cenonogastra microrhophalae (Ashmead) included as portion of that for O. dimidiatus.

Table 4.2. Mean number of L. trifolii and total, larval and larval-pupal parasitoids reared per two trifoliates of celery adjacent to castor bean, from two sites at Belle Glade, FL, 1985[a].

Distance (m)[b]	L. trifolii[c]	Parasitoids		
		Total[c]	Larval	Larval-pupal
3	4.57	1.58	1.08	0.50
8	5.15	1.55	0.93	0.62
13	4.05	1.60	0.80	0.80
18	3.57	1.45	0.82	0.63
23	3.10	1.60	1.00	0.60
28	3.10	2.20	1.50	0.70

[a]All means in columns not significantly different by Duncan's new multiple range test ($P<0.05$).
[b]Distance from castor bean at which samples taken.
[c]Log10(x+1) transformation before analysis; untransformed data presented.

were greater, though not significantly, near castor bean, parasitoid abundance exhibited no such trend and, in fact, appeared greatest at distances farthest from the weed. Analysis of percent parasitism of mines also failed to indicate any significant influence of castor bean on natural enemy occurrence (Table 4.3.).

Approximately midway through the study (ca. May 15) almost all labelled castor bean plants at one site had been severely defoliated by an unknown disease. Therefore, results derived from data produced at both sites may not adequately estimate the effect of castor bean as the plants at the affected site (site one) contained considerably less foliage than those at the unaffected site (site two). Thus, data from site two were analyzed separately to perhaps better ascertain castor bean's role.

Number of adult L. trifolii and parasitoids reared per two trifoliates from site two did not vary significantly with distance from castor bean (Table 4.4). However, movement of parasitoids from the weed to celery is implicated as percent parasitism by larval-pupal species nearest castor bean was significantly greater than that occurring 23 m away (Table 4.5). As these parasitoid species are the most abundant reared from Liriomyza on castor bean, the higher rates at which L. trifolii is attacked by them in adjacent celery may indicate the potential of castor bean as a harborage for these natural enemies.

Table 4.3. Mean percent total, larval and larval-pupal parasitism of L. trifolii per two trifoliates of celery adjacent to castor bean from two sites at Belle Glade, FL, 1985[a,b].

Distance (m)[c]	Total	Larval	Larval-pupal
3	36.4	22.7	13.7
8	33.0	16.7	16.3
13	31.9	16.8	15.1
18	31.7	19.7	12.0
23	38.3	29.8	8.5
28	34.8	23.7	11.1

[a] All means in columns not significantly different by Duncan's new multiple range test ($P<0.05$).
[b] Arcsine ($\sqrt{x}$) transformation before analysis; untransformed data presented.
[c] Distance from castor bean at which samples taken.

Table 4.4. Mean number of L. trifolii and total, larval and larval-pupal parasitoids reared per two trifoliates of celery adjacent to castor bean, Belle Glade, FL, 1985[ab].

Distance (m)[c]	L. trifolii[d]	Parasitoids		
		Total[d]	Larval	Larval-pupal
3	3.25	2.00	1.45	0.55
8	3.50	1.85	1.30	0.55
13	3.85	1.75	1.05	0.70
18	3.10	2.00	1.25	0.75
23	3.10	1.60	1.00	0.60
28	3.10	2.20	1.50	0.70

[a] Site two only.
[b] All means in columns not significantly different by Duncan's new multiple range test ($P<0.05$).
[c] Distance from castor bean at which samples taken.
[d] Log10(x+1) transformation before analysis; untransformed data presented.

Table 4.5. Mean percent total, larval and larval-pupal parasitism of L. trifolii per two trifoliates of celery adjacent to castor bean, Belle Glade, FL, 1985[ab].

Distance (m)[c]	Total[d]	Larval[d]	Larval-pupal[e]
3	48.6	24.1	24.5 a
8	45.7	24.9	20.8 ab
13	27.9	16.1	11.8 ab
18	34.3	20.6	13.7 ab
23	38.2	29.8	8.5 b
28	34.8	23.7	11.1 ab

[a]Site two only.
[b]Arcsine ($\sqrt{x}$) transformation before analysis; untransformed data presented.
[c]Distances from castor bean at which samples taken.
[d]Means in columns not significantly different by Duncan's new multiple range test ($P<0.05$).
[e]Means followed by same letter not significantly different by Duncan's new multiple range test ($P<0.05$).

Populations of adult leafminers and parasitoids in celery based on sticky trap collections did not peak until the eighth week of sampling, ca. June 6 (Figure 4.2). The greatest mean number of L. trifolii collected per trap was 7.75 while a mean of 8.95 parasitoids were trapped the same sampling period. (Traps at site two were covered with dust blown from an adjacent disked field on the last sampling date, June 20, making collection and identification of adults impossible. Results of catches for this date, therefore, were obtained only for site one.)

Musgrave et al. (1975a) trapped a maximum mean per sticky trap of 10.05 L. sativae adults in cucurbits and 9.69 parasitoids in legumes. They believed yellow sticky trap cards were the preferred method of estimating leafminer populations due to speed and ease of handling. Other maximum catches per trap of Liriomyza species reported are 22.4 (Chandler 1981) in alfalfa and 44.0 (Tryon et al. 1980) in tomatoes. Genung (1981) trapped 13.8 parasitoids per daylight hour (over six h) per trap in the weed creeping cucumber, Melothria pendula L.

All Liriomyza trapped during the entire study were L. trifolii except for one L. sativae trapped on May 30. At least six species of parasitoids, the vast majority of them larval, were collected representing four families of Hymenoptera (Table 4.6). Although most species were identifiable, sticky material used to trap adults often

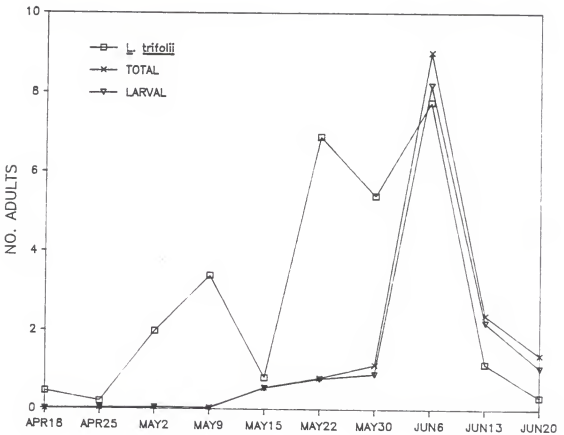

Figure 4.2. Mean number of L. trifolii and total and larval parasitoids collected per yellow sticky trap in celery adjacent to castor bean, from two sites at Belle Glade, FL (1985).

Table 4.6. Hymenopteran parasitoids of L. trifolii collected on sticky traps in celery adjacent to castor bean, from two sites at Belle Glade, FL, 1985.

Family	Species	Abundance (%)
Braconidae	Opius spp.* and Oenonogastra microrhophalae	7.4
Cynipidae	Ganaspidium sp.	0.3
Eulophidae	Diglyphus intermedius	43.6
	Chrysonotomyia punctiventris	47.2
	Chrysocharis parksi	0.2
Pteromalidae	Halticoptera circulus	1.3

* Includes Opius dimidiatus, O. dissitus and O. brunneipes.

covered the individuals and made discrimination between species of Braconidae virtually impossible. However, specimens of Braconidae trapped may include all species reared from trifoliates.

Although the majority of parasitoids caught in traps were eulophids, this result may not reflect the true composition of adult parasitoids in celery adjacent to castor bean. Over 38% of parasitoids reared from trifoliates were braconids compared to less than eight percent found on sticky traps. This disparity may result from a greater attraction to yellow cards of eulophids than braconids. Genung (1981) reported the majority of parasitoids caught on yellow sticky traps in weeds adjacent to celery were chalcids including eulophids, however no studies have been conducted to determine the relative attractiveness of leafminer parasitoids to various colored traps.

Significantly more adult parasitoids, particularly larval species, were caught in traps closest to castor bean than those occurring 23 and 28 m away (Table 4.7). Occurrence of larval-pupal species, the densities of which were too low to affect patterns of total parasitoid abundance, did not differ with distance from castor bean. Catches of L. trifolii exhibited a pattern of decreasing abundance with increasing distance, although not a significant one.

Table 4.7. Mean number of L. trifolii and total, larval and larval-pupal parasitoids collected per sticky trap in celery adjacent to castor bean, from two sites at Belle Glade, FL, 1985[a].

Distance (m)[b]	L. trifolii[c]	Parasitoids		
		Total[d]	Larval[d]	Larval-pupal[d]
3	3.34 a	2.44 a	2.28 a	0.16 a
8	3.35 a	1.67 ab	1.56 ab	0.11 a
13	3.23 a	1.64 ab	1.41 ab	0.23 a
18	2.94 a	1.35 ab	1.19 ab	0.16 a
23	2.22 a	0.58 b	0.50 b	0.09 a
28	1.78 a	0.53 b	0.44 b	0.09 a

[a]Means in columns followed by same letter not significantly different by Duncan's new multiple range test ($P<0.05$).
[b]Distance from castor bean at which collections were made.
[c]Log10(x+1) transformation before analysis; untransformed data presented.
[d]$\sqrt{x+.5}$ transformation before analysis; untransformed data presented.

Results from samples taken at site two failed to reveal any possible effect of the weed on adult numbers in celery (Table 4.8). Significantly fewer larval parasitoids were caught at site two than at site one (Table 4.9) for those dates when populations were greatest (June 6 and 13). Castor bean may have attracted parasitoids from the celery, thus affecting trap catches. Also, rows within celery were generally more weed-free at site one, therefore, the yellow traps may have been more visible and, thus, more attractive to parasitoids there than at site two. Or perhaps other factor(s) such as site location affected number and composition of parasitoids occurring or their susceptibility to being trapped.

Mean number of larval-pupal species trapped did not differ significantly for plots at site one and site two during the entire study (Table 4.9). Their generally low abundance in celery was apparently unaffected by abundance or scarcity of adjacent castor bean or other factors mentioned above which may have influenced larval parasitoid population numbers.

Results of this study remain largely inconclusive. Clearly, radiation dosages greater than that used (0.1 microcurie per ml) should be incorporated in castor bean to sufficiently label, for several weeks, leafminers and parasitoids developing within foliage. However, transplanting plants exposed to higher dosages to the field is potentially environmentally unsound (H.L. Cromroy,

Table 4.8. Mean number of L. trifolii and total, larval and and larval-pupal parasitoids collected per sticky trap in celery adjacent to castor bean, Belle Glade, FL, 1985[a,b].

Distance (m)[c]	L. trifolii[d]	Parasitoids		
		Total[e]	Larval[e]	Larval-pupal[e]
3	2.25	0.91	0.72	0.19
8	3.05	0.69	0.58	0.11
13	2.39	1.11	0.86	0.25
18	1.69	1.08	0.89	0.19
23	2.22	0.58	0.50	0.08
28	1.78	0.53	0.44	0.09

[a] Site two only.
[b] All means in columns not significantly different by Duncan's new multiple range test ($P<0.05$).
[c] Distance from castor bean at which collections were made.
[d] Log10(x+1) transformation before analysis; untransformed data presented.
[e] $\sqrt{x+.5}$ transformation before analysis; untransformed data presented.

Table 4.9. Mean number of L. trifolii (LT) and total (TP), larval (LP) and larval-pupal (LPP) parasitoids collected per sticky trap in celery adjacent to castorbean, Belle Glade, FL, 1985.

Date	Species	Site One	Site Two
Apr 18	LT	0.44	0.46
	TP	0.00	0.00
	LP	0.00	0.00
	LPP	0.00	0.00
Apr 25	LT	0.31	0.12
	TP	0.00	0.04
	LP	0.00	0.04
	LPP	0.00	0.00
May 2	LT	1.31	2.41
	TP	0.00	0.08
	LP	0.00	0.08
	LPP	0.00	0.00
May 9	LT	2.44	4.00
	TP	0.12	0.00
	LP	0.06	0.00
	LPP	0.06	0.00
May 15	LT	0.75	0.83
	TP	0.50	0.83
	LP	0.50	0.83
	LPP	0.00	0.00

Table 4.9 continued.

Date	Species	Site One	Site Two
May 22	LT	7.44	6.50
	TP	1.06	0.62
	LP	1.00	0.62
	LPP	0.06	0.00
May 30	LT *	8.75	3.12
	TP	1.19	1.08
	LP	1.00	0.83
	LPP	0.19	0.25
Jun 6	LT *	15.81	2.37
	TP *	15.44	4.71
	LP *	14.94	3.66
	LPP	0.50	1.05
Jun 13	LT *	2.50	0.25
	TP *	5.56	0.25
	LP *	5.25	0.16
	LPP	0.31	0.09

* Means in these rows significantly different by t-test ($P<0.05$).

personal communication, 1985). Therefore, other methods of detection such as activation analysis or X-ray micropoble elemental analysis may need to be implemented to determine castor bean's effect.

Analysis of collection data also failed to detect any such effect. Although some data suggest leafminer and parasitoid abundance is greater in celery nearest castor bean, further studies entailing several years of sampling, not only from celery but from castor bean, are required before the role of this weed within the celery agroecosystem of southern Florida can be adequately assessed.

Host Preference

Liriomyza sativae preferred castor bean over celery for oviposition, as a total of only two larvae were observed on all celery seedlings offered (Table 4.10). Liriomyza trifolii females preferred celery as a host, although they produced more progeny on their less preferred host (castor bean) than L. sativae females did on celery.

Progeny production of these individuals is less than that of females in previous studies. Leibee (1984) found L. trifolii females produced an average of greater than 16 eggs per day at 4.5 d of age while Parrella et al. (1983b) recorded a mean daily viable egg production of 17.3 for L. trifolii on celery. Low mean progeny production resulted in part from extreme variability in oviposition by individual females. Egg deposition (based on larval counts) by L.

Table 4.10. Mean number of larvae, pupae and adults of Liriomyza spp. produced on celery and castor bean offered simultaneously to females for oviposition[a,b].

life stage	L. sativae		L. trifolii	
	celery	castorbean	celery	castorbean
larvae	0.13 a	22.33 b	23.19 a	5.38 b
pupae	0.00 a	19.33 b	16.00 a	4.13 b
adults	0.00 a	15.73 b	12.56 a	3.06 b

[a]Mean number per four females in 48 h.
[b]Means in rows for each Liriomyza sp. followed by same letter not significantly different by t-test ($P<0.05$).

sativae in castor bean occurred in only eight of the 15 cages as a mean of 41.9 larvae per four females were produced in these cages. Four L. trifolii females produced a mean of 33.7 larvae in the 11 cages where oviposition occurred.

Leibee (1984) and Parrella et al. (1983b), however, followed female oviposition over entire lifetimes. The exposure period of only 48 h used in this study may not have allowed females enough time to produce or begin producing progeny at their maximum rates. Leibee (1984) and Parrella et al.(1983b) also used smaller cages to expose plants to flies. Female Liriomyza contained in closer proximity to host plants may oviposit sooner and more often than those in a larger cage. Also, females may not have adequately acclimated to cage conditions within 48 h to begin ovipositing at rates representing their normal potential on these host plants.

Liriomyza species' preference in the laboratory for celery and castor bean as host plants for oviposition may provide insights into factors affecting field populations where celery and castor bean are in close proximity to one another. Rejection of celery for ovipositon by L. sativae is not surprising as it was not collected from celery in the preceding field study and has not been found on this crop in recent years in Florida (Leibee 1984). Considering L. sativae is the most abundant Liriomyza species found on castor bean and the same complex of parasitoids attacks L.

sativae and L. trifolii, castor bean, in certain situations, could be considered beneficial as a source of natural control agents for L. trifolii in celery.

CHAPTER V
BIOLOGY OF *Liriomyza sativae* BLANCHARD ON CASTOR BEAN

Introduction

Liriomyza trifolii (Burgess) has recently emerged as the dominant leafminer species affecting celery in Florida and California (Leibee 1984, Trumble and Toscano 1983). Weeds adjacent to celery fields of south Florida are reported to affect leafminer and leafminer parasitoid abundance in celery nearest weeds (Genung and Janes 1975, Genung et al. 1978, Genung 1981). Stegmaier (1981) cited castor bean, *Ricinus communis* L., as an important host of *Liriomyza* in south Florida. This weed was found to harbor large numbers of *L. trifolii*, *L. sativae* (a very similar species) and several species of parasitoids known to attack both leafmining pests (Chapter Three).

Castor bean is fairly common to the celery-growing region of south Florida. Since *L. sativae* is the predominant *Liriomyza* species occurring on this weed (Chapter Three), an understanding of the biology of the species on this weed may help in understanding the factors affecting *Liriomyza* population dynamics within the celery agroecosystem. This is especially true since certain parasitoids are known to attack both *L. sativae* and *L. trifolii* (Chandler 1982). Objectives of this study were to

determine development times for egg, larval and pupal stages at 20, 25, 30 and 35° C and oviposition rate and fecundity of L. sativae on castor bean.

Methods and Materials

Development at Constant Temperatures

Four groups of 50 female and 20 male L. sativae, three to four days old, were taken from the colony maintained at EREC and each placed in 66 cm high x 36 cm wide x 36 cm deep wood and screen cages, each containing nine 10-14 day-old castor bean plants. The plants were held in Ehrlenmeyer flasks containing Hoagland's solution and were plugged around the plant stems with cotton. After being exposed to adult leafminers for 24 h, the plants were placed into four separate environmental chambers maintained at 20, 25, 30 and 35° C, 55 ± 10% RH and a photoperiod of L:D 14:10. Groups (cages) of plants were not exposed simultaneously and all plants within a cage were placed in the same chamber, i.e. maintained at the same temperature.

Development of resulting leafminer progeny was observed and noted daily. No more than eight larvae were allowed to develop per leaf as excess larvae were destroyed within their mines with an insect pin. When the majority of larvae within a leaf had developed to third instar, the leaf was excised and placed in a petri dish containing moist

filter paper. Inspection for development was then increased to twice daily.

After all larvae within a leaf had completed development, puparia were placed individually into gelatin capsules for adult emergence. Occurrence of leaf-exit by mature larvae, pupation and adult emergence for each progeny was noted to determine mean development times for egg-larval (combined egg and larval stages) and pupal stages.

Lifetime Oviposition

A female and two males (<24 h old) were confined in a 23 cm high x 20 cm wide x 20 cm deep plexiglass and screen cage containing two castor bean plants (five to seven d old) for ovipostion. Plants were held in the same manner as those in the previous study. Honey water was smeared on the screen sides as a source of carbohydrates for the flies.

Exposed plants were replaced every two days until death of the female. If both males died before the female, another one less than 24 h old was provided. Number of resulting larvae, puparia and adults and sex of adults was noted. A cage with adult flies was replicated 11 times and maintained at 25^{o} C, 55 $\pm$ 10% RH and a photoperiod of L:D 14:10.

Results and Discussion

Development at Constant Temperatures

The development times for the combined egg and larval stages were inversely proportional to temperature for all temperatures (Figure 5.1 and Table 5.1), however, development times at 30 and 35° C were essentially equal. Charlton and Allen (1981) reported similar effects on development of L. trifolii on eggs and larvae on pink beans. Leibee (1984) found egg development time varied little from 25 to 35° C for L. trifolii on celery noting evaporative cooling of leaves may have negated any effects of increased ambient air temperature. Evaporative cooling by castor bean leaves may explain why development times of combined egg and larval stages of L. sativae at 30 and 35° C were approximately equal.

Pupal development times were also inversely proportional to temperature (Figure 5.1 and Table 5.1). None of the 27 pupae formed at 35° C completed development indicating this temperature is approximately the upper lethal temperature for the pupal stage of L. sativae. Leibee (1984) reported only 9.4% survival of L. trifolii pupae at 35° C and Parrella et al. (1981b) found no adult emergence at 37.8° C for L. trifolii. Pupal survival of L. sativae at lower temperatures, however, was somewhat less than reported for L. trifolii at similar temperatures (Leibee 1984, Parrella et al. 1981b). Tryon and Poe (1981)

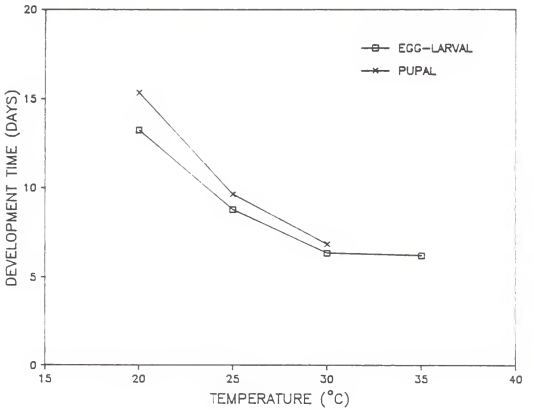

Figure 5.1. Relationship of development time to temperature (°C) for the combined egg and larval (egg-larval) stage and the pupal stage of L. sativae on castor bean.

Table 5.1. Development time (DT), development rate (DR), thermal units in degree days (TU) and development threshold (D Th) for life stages, and pupal survival for L. sativae on castor bean at 20, 25, 30 and 35° C.

Temp (°C)	Egg-larva (days)	Pupa (days)	Total	Pupal survival (%)
20				
DT±S (n)	13.22 ± 0.12(38)	15.33 ± 0.15(27)	28.55	71.1
DR	7.56	6.52	---	
TU	192.15	121.59	313.74	
25				
DT±S (n)	8.75 ± 0.10(65)	9.61 ± 0.09(46)	18.36	71.0
DR	11.43	10.41	---	
TU	170.93	124.27	295.20	
30				
DT±S (n)	6.31 ± 0.04(66)	6.81 ± 0.05(43)	13.12	65.2
DR	15.84	14.68	---	
TU	154.82	122.11	276.93	
35				
DT±S (n)	6.17 ± 0.10(27)	---	---	0.0
DR	16.21	---	---	
TU	182.23	---	---	
D Th	5.47	12.07		

reported 75% emergence for L. sativae and its parasitoids on celery at temperatures above 21.1° C, a survival rate very similar for this species on castor bean (Table 5.1). This indicates that the adult emergence rate of L. sativae may be lower than that for L. trifolii which has been reported as high as 92.5% at 26.7° C (Parrella et al. 1981b).

Regression equations for linear relationships between temperature and development rate (Figure 5.2) are presented in Table 5.2. Although the equation for pupal development is similar to those reported by Leibee (1984) (y = 0.76X - 7.79) and Tryon and Poe (1981) (y = 0.78X - 7.45) for L. trifolii and L. sativae pupae, respectively, on celery, the differences are great enough to indicate a possible host plant effect on development biology. Likewise, the development thresholds predicted from the regression equations (Table 5.1) were dissimilar from that found by Leibee (1984). Host plant effects on immature leafminer biology were evident in studies by Parrella et al. (1983b) who found significantly greater survival for L. trifolii larvae on chrysanthemum and celery than on tomato and Charlton and Allen (1981) who reported slower development times for L. trifolii on `Show-off' chrysanthemums than on pink beans.

Lifetime Oviposition

Daily oviposition rate measured as mean number of larvae produced per female peaked at 25.5 when females were

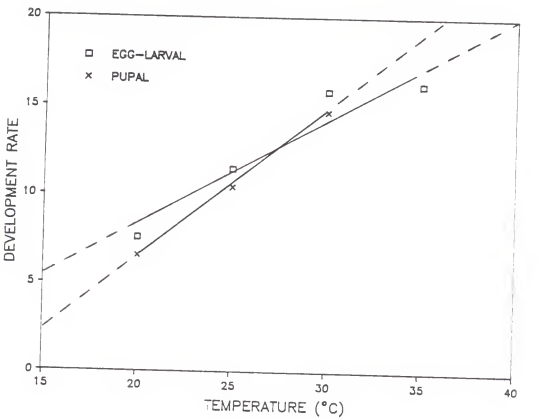

Figure 5.2. Relationship of development rate (1/days x 100) to temperature (°C) for the combined egg and larval (egg-larval) stage and the pupal stage of L. sativae on castor bean.

Table 5.2. Linear regression equations and r values for development rate and temperature (^{o}C) for egg-larval and pupal stages of L. sativae on castor bean.

Stage	Temp (^{o}C) used in regression	* equation	r
Egg-larva	20, 25, 30, 35	y = 0.58X - 3.18	0.96
Pupa	20, 25, 30	y = 0.82X - 9.86	0.98

* y = 1/days x 100.

five days of age (Figure 5.3). Total average fecundity ± SE of females was 164.5 ± 45.7 resulting in 98.6 ± 25.7 adults with a male to female sex ratio of 1.0:1.1. Average longevity of females was 13.4 ± 2.3 d; one individual died at one day of age while two survived to 19 d.

Female age apparently had no effect on survival and sex ratio of progeny (Table 5.3) although pupal survival appears greatest when females were 13 d of age and older. Older females were less fecund (Figure 5.3); therefore developing larvae had less competition for food resources possibly resulting in increased fitness and survival of the subsequent (pupal) stage. Average total pupal survival (86.1%) was somewhat greater than that for pupae at 25° C in the preceding study (71.0%). All puparia produced during one exposure period for one female were held in petri dishes containing moistened filter paper opposed to puparia formed in the previous study which were held individually in gelatin capsules. The wet paper may have increased humidity within the petri dishes and this may have enhanced pupal survival whereas some dessication of puparia may have occurred in the gelatin capsules.

Leibee (1984) found L. trifolii at 25° C to produce an average of 288.3 eggs during a lifespan of 16.8 d utilizing celery as a host. Charlton and Allen (1981) reported a lifetime fecundity per L. trifolii female of 439 eggs on blackeye peas. The superior reproductive potential of L.

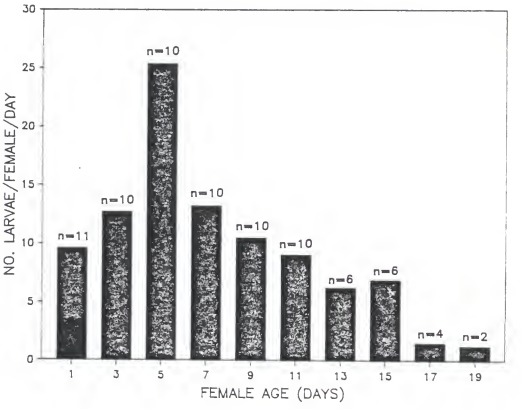

Figure 5.3. Mean number of larval progeny produced per female per day throughout the life of L. sativae on castor bean at 25° C.

Table 5.3. Percent survival of larval and pupal progeny and sex ratio of resulting adults for L. sativae on castor bean at 25° C.

Age[a]	N[b]	% Survival		Sex ratic (female:male)
		Larvae	Pupae	
1	11	73.4	82.5	1:0.9
3	10	64.2	86.5	1:0.9
5	10	61.7	80.2	1:0.9
7	10	65.2	82.0	1:0.9
9	10	83.3	86.3	1:0.9
11	10	80.1	86.9	1:1.0
13	6	90.4	89.4	1:1.2
15	6	89.1	89.7	1:0.9
17	4	75.0	100.0	1:1.2
19	2	80.0	100.0	1:0.3

[a]Cumulative age of females in days.
[b]Number of females surviving.

trifolii compared to that of L. sativae and other Liriomyza species may explain the former species evolution of pesticide resistance and adaptability to a wide range of host plants resulting in its current pest status (Parrella and Keil 1984). The reproductive biology of L. sativae on castor bean, however, may not represent this leafminer's true potential as would occur on a more suitable host. Although castor bean is readily attacked by L. sativae, certain characteristics of the plant, such as the presence of the proteinaceous toxin ricin in plant tissues (Weiss 1971), may inhibit and reduce progeny development and survival.

Results of this study indicate castor bean to be a suitable host for L. sativae. Although its reproductive performance is not as great as that of L. trifolii, its potential, at least on young castor bean plants, is still considerable. Based on this study, maximum population growth of L. sativae on castor bean should occur at air temperatures from 25 to 30° C. Laboratory studies conducted under ideal conditions, however, can only approximate field situations. More research is needed to better quantify factors, especiallly parasitism, which affect and regulate Liriomyza populations on wild and crop hosts to adequately predict future leafminer population dynamics.

CHAPTER VI
CONCLUSIONS

The preceding studies should help elucidate the potential of castor bean as a host for Liriomyza species in the celery-growing region of south Florida and the weed's possible effects on leafminer and leafminer parasitoid population dynamics within celery where it occurs adjacent to the crop. Even where stands of castor bean are not in close proximity to celery fields, mid to long distance migration of leafminers and parasitoids may still occur particularly if prevailing winds, found to facilitate leafminer movement (Tryon et al. 1980), move from the weed in the direction of fields.

Castor bean, particularly young plants, was readily attacked by L. sativae and L. trifolii with the latter comprising over 36% of adults reared from foliage during late spring and early summer 1984. This supports Genung and Janes (1975) who reported the possible occurrence of this pest on the weed near Belle Glade. The harborage of L. trifolii by castor bean may expand the pest status of this weed to include not only those plants invading fields but those occurring outside of, but near, fields which can serve as sources of the pest. The occurrence of a large parasitoid complex (11 species) found to attack Liriomyza on

castor bean, however, does impart a beneficial role to the weed.

Except from late summer to mid-fall and during the coldest weeks of winter, Liriomyza was found on castor bean year-round (August 1984-July 1985) in the Belle Glade area. Population density, determined during this period on older plants, however, never approached that occurring earlier in 1984 on younger ones (< four months old). Regrowth on older plants, which appeared in late winter, probably had a thicker epidermis than foliage of young plants. Liriomyza females may have found the regrowth unsuitable as ovipositon substrates or less desirable than other available hosts. Established stands of castor bean near celery fields in south Florida generally occur on canal ditchbanks and consist of older plants which may contain relatively few Liriomyza. Younger foliage is present, however, as seedlings constantly appear, especially in spring, under and around the mature plants (personal observation). Thus, even older stands of castorbean can serve as sources of Liriomyza and their parasitoids.

Although sampling data suggest leafminers and parasitoids may migrate from castor bean to adjacently planted celery, study results were inconclusive in quantifying the extent of the weed's effect on populations within the crop. Attempts to detect migration by labelling developing Liriomyza and parasitoids within castor bean by incorporating the isotope ^{35}S in the plants were

unsuccessful. Rapid plant growth possibly dispersed the isotope to concentrations too low to be encountered by developing individuals. If ^{35}S was incorporated in insect tissues, the concentrations were at such levels as to be undetectable by autoradiography or liquid scintillation analysis. Possible dilution of isotopes and other tracer compounds by rapid plant growth should be considered when utilizing this method for labelling insects.

Liriomyza females exhibited definite host preferences for either castor bean or celery in the laboratory. Although females attacked castor bean, L. trifolii preferred celery as an oviposition substrate while celery was virtually rejected by L. sativae as a host plant. Though once considered the major leafminer species attacking celery in Florida (Musgrave et al. 1975b), L. sativae may have recently developed a nonpreference for this plant, perhaps as a result of its displacement from the celery "niche" by L. trifolii. L. trifolii's propensity to develop resistance to insecticides (Leibee 1981) and its superior reproductive potential (Parrella and Keil 1984) have possibly given it a selective advantage over L. sativae, thus allowing it to outcompete and displace the latter in celery in Florida (Poe and Montz 1981) and, apparently, in California (Trumble 1981).

The biology of L. sativae on castor bean in the laboratory proved different from that of L. trifolii reported on other hosts (Charlton and Allen 1981, Parrella

et al. 1983b, Leibee 1984). The reproductive potential of L. sativae was less than that previously reported for L. trifolii, but was still considerable since a female could produce ca. 90 female progeny during her lifetime on castor bean. Even under the most ideal conditions, however, reproductive capabilities for L. sativae in the field are probably considerably less than that found in the laboratory as the majority of stands of castor bean consist of older plants, the foliage of which, as noted above and in Chapter Three, does not appear as suitable for leafminer oviposition and development as younger foliage.

Although the preceding studies have expanded our knowledge of castor bean's potential as a host and reservoir of Liriomyza and their parasitoids in the Belle Glade area, more field research is needed to fully understand the weed's role within the celery agroecosystem. Several years of sampling are required before adequate determinations can be made about the exact composition and abundance of leafminers and parasitoids throughout the seasons. This information is necessary to predict leafminer infestation levels and to develop a broad-ranging celery pest management program. Determination of the extent of migration of Liriomyza and parasitoids from chemically or mechanically destroyed castor bean stands into nearby celery would also be worthwhile since our understanding of how a weed species might be manipulated to influence arthropod populations within host crop fields would be increased. Equally worthwhile is the

education of commercial growers, ideally the primary beneficiaries of such research, on the role weeds such as castor bean can play within the crop ecosystem and how these plants can potentially be utilized as an integral component of a pest management program.

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BIOGRAPHICAL SKETCH

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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